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THE INFLUENCE

OF A

MAGNETIC FIELD UPON THE SPARK SPECTRA OF IRON AND TITANIUM

BY

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INTRODUCTION.

The investigation of which an account is given in the following pages was carried out during the year 1910 in the Pasadena laboratory of the Solar Observatory. The object was to obtain as complete data as possible concerning the influence of a magnetic field on the spectra of iron and titanium through a considerable range of wave-length, and to present this in such form as would be useful for reference in connection with questions concerning the effect of a magnetic field on the spectrum lines, such as those arising in investigations on sun-spots, as well as for comparison with the known phenomena of the Zeeman effect for spectra other than those of iron and titanium. The tables are designed to give an accurate description of all lines between λ3700 and λ6700, so far as it has been possible to photograph them. The measurements of magnetic separations for each spectrum through this range show clearly the degree in which the separation changes with the wave-length. The complex types as well as the simpler are studied with reference to the prevalence of a fundamental interval between the components. Numerous cases are noted of the recurrence of certain types of separation, and while the search for series relations in these many-lined spectra has not proved fruitful, the descriptions of the type of separation show whether certain lines are possibly connected, or whether they unquestionably arise from different radiating particles. A few cases of dissymmetry among components are given in the tables. It has been possible, by reason of the large amount of material collected, to make a detailed comparison between the Zeeman separation and the displacement of lines produced by pressure around a light source, and it is shown to what degree a correspondence exists. The reproductions of spectra which are given are of selected regions showing the various types of magnetic separation and the behavior of groups of lines which are of special interest in other investigations on these spectra.

The desirability of making the material as complete as possible has necessitated photographing the weaker lines in these two spectra so far as they were obtainable, a condition which has added to the labor and altered to some extent the experimental methods that would have been used for the stronger lines alone. The tables for titanium contain all but the weakest of those lines given in the regular lists of arc and spark lines. As much can not be claimed for iron, however, as numerous lines, fairly strong in the arc, are not brought out by the spark in the magnetic field even with an exposure of many hours. This is especially true of lines of diffuse appearance, which are particularly numerous in the iron spectrum.

The results of a number of investigations on the Zeeman effect for certain parts of the iron spectrum have been published, and will be spoken of in the historical summary to follow. These are fragmentary, however, with some discordances, and it is believed that there is little real duplication in the present paper, even for those parts of the spectrum which have been treated to some extent by others.

THEORY AND FORMER INVESTIGATIONS.

1. General.

It is not the purpose of the author to give here in any detail the development of the theory of the Zeeman effect or to summarize at length the many investigations which have led to the present state of knowledge regarding the phenomenon. Several such accounts have appeared in publications which are usually accessible. Among these may be mentioned the memoir of Cotton (1)* (1899), the chapter by Runge in Kayser's *Handbuch der Spectroscopie* (2) (1902), the detailed discussion by Voigt (3) (1908) in connection with the related optical phenomena, and the brief treatment by Lorentz (4) (1909) in his Columbia Lectures. Of these the second is by far the most complete, covering fully the historical development, methods of investigation, and the theory and spectroscopic results contained in the literature up to that time. For the purposes of the present paper, we shall consider the points in the theory which apply closely to the results of this investigation, and summarize the work of other investigators in so far as their results relate directly to those of the present research.

The later work on the Zeeman phenomenon has been concerned largely with the study of complex and unusual types of separation. It was shown during the earlier investigations by Zeeman (5), Michelson (6), Preston (7), Cornu (8), Becquerel and Deslandres (9), (10), Ames, Earhart and Reese (11), Reese (12), and Kent (13) that a large proportion of the spectrum lines of any of the elements that have been examined are split into more than three components. This involved an extension of the original theory of Lorentz, which satisfactorily explained the triplet separation, in which two components are given by the light vibrations in a plane perpendicular to the lines of magnetic force, these showing respectively a right-handed and a left-handed circular polarization, and a central component by the light vibrations parallel to the magnetic force-lines. Since the phenomenon in its simplest form justified taking the electron theory as the basis of all conceptions of the action of the magnetic field upon spectra, a series of investigations, among which those of Lorentz (14), Larmor (15), Voigt (16), and Robb (17) may be mentioned, have greatly extended the mathematical theory, both for radiation in general and for the explanation of the more complex forms of magnetic separation. Voigt and Robb have based their theory on the idea of mutually connected systems of electrons, and have thus been able to account for many of the more complicated types of Zeeman separation. However, both the nature of the connections and the way the magnetic field effects such systems are but imperfectly explained.

The proportionality of separation of components to field-strength has been worked on by Reese (12), Kent (13), Runge and Paschen (18), Färber (19), Weiss and Cotton (20), Paschen (21), and Stettenheimer (22), and established to a very close approximation. The law enunciated by Preston (23) that the character of separation and distance between components (measured in terms of change of vibration frequency) is the same for corresponding lines in the series of Balmer, Rydberg, and Kayser and Runge has been investigated by Reese (12), Kent (13), Runge and Paschen (24), Runge and Precht (25), Miller (26), and Lohmann (27). The last two have found some exceptions, though Runge and Paschen observed very close agreement for the series lines of a number of elements. This relation has frequently been used, recently by Moore (28), in an attempt to find series among spectra containing many lines.

There has been considerable work in recent years on the commensurability of the separations of spectrum lines, that is, on the existence of a fundamental interval of which the separations of all complex lines are multiples, and on the extent to which this applies to the separations of triplets in which

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* Numbers in parentheses indicate references to the literature on p. 65.

there is always a great diversity for the lines of the same element. As this point will receive a good deal of attention in the consideration of the results for the spectra of iron and titanium, it may be well to go briefly into this portion of the theory.

If the Zeeman phenomenon were in full accord with the simplest form of the electron theory as given by Lorentz, all lines would show the separation of the "normal triplet," in which the distance of each side component from the central line would be given by the relation

$$\Delta\lambda = \frac{e}{m} \cdot \frac{\mathrm{H}\,\lambda^2}{4\pi v}$$

where e/m is the ratio of charge to mass of the electron, H the field-strength, and v the velocity of light. This is derived (2a) from the fact that the change of period of the light producing one side component is $e\mathrm{H}/2m$ in 2π seconds, or $e\mathrm{H}/4\pi m$ vibrations in one second. The number of vibrations per second is $n = v/\lambda$. The change of frequency is then

$$dn = \frac{v d\lambda}{\lambda^2} = \frac{e\mathrm{H}}{4\pi m}$$

from which

$$\Delta\lambda = \frac{e}{m} \cdot \frac{\mathrm{H}\lambda^2}{4\pi v}$$

If v be expressed in centimeters per second, the change in frequency per cm length is

$$\frac{\Delta\lambda}{\lambda^2} = \frac{e}{m} \cdot \frac{\mathrm{H}}{4\pi v}$$

The factor e/m is here expressed in electro-magnetic units. This value of $\Delta\lambda/\lambda^2$ for a given field determines the separation of the side components of the "normal triplet" from the central line, and a considerable number of lines in a spectrum will usually give a value of e/m in close agreement with that obtained for cathode rays. The separation of the majority of triplets, however, differs from the normal type, though sometimes by even multiples. This means either that there are real differences in the values of e/m for different negative electrons, or that the relation derived from the elementary theory is not sufficiently general. Lorentz inclines to the latter view (4a). In discussing this question, Voigt (3a) observes that it is by no means certain that the field acting upon a given electron is the same as that which we measure by one of our regular methods. The field due to the movement of charged parts of the molecule itself must be recognized as possibly superposed on the external field due to the magnet.

The elementary theory does not provide for the more complicated types of separation, nor does any extension so far worked out cover them satisfactorily. However, an examination of the results of Runge and Paschen (18) (24) for several elements and of Lohmann (27) for the spectrum of neon (with the echelon spectroscope) enabled Runge (29) to enunciate the following:

> Die bisher beobachteten komplizierten Zerlegungen von Spektrallinien im magnetischen Felde zeigen die folgende Eigentümlichkeit: Die Abstände der Komponenten von der Mitte sind Vielfache eines aliquoten Teil des normalen Abstándes
>
> $$a = \frac{\Delta\lambda}{\lambda^2} = \frac{e}{m} \cdot \frac{\mathrm{H}}{4\pi v}$$
>
> Sicher beobachtet sind bisher die Teile $a/2$, $a/3$, $a/4$, $a/5$, $a/6$, $a/7$, $a/11$, $a/12$.

This work of Runge is regarded by Voigt as showing that the internal field acting on the electron can have little effect, that the electrons within the molecule have the same value of e/m as that of cathode rays.

Such a relation between the separation for individual lines and that of the normal triplet is of high interest when applied to spectra containing many lines. It has been examined by Moore (28) for the spectra of barium, yttrium, zirconium, osmium, and thorium, and relations similar to those observed by Runge have been obtained. The objection can be raised to this method that, by choosing small fractions of the interval a and correspondingly large multiples, the difference between the calculated and observed values can be made as small as we please and brought within the errors of measurement. Runge gives a criterion as to how far it is allowable to go in such calculations. This question of commensurability will receive attention in the following study of the iron and titanium spectra.

Dissymmetry in the separation and in the intensity of components on the red and violet sides has been observed many times in Zeeman investigations. Voigt (3*b*) arrived at the conclusion that light observed at right angles to the force-lines should give a triplet whose red component is slightly closer to the central line and stronger than the violet component. Observations by Zeeman (30) on the iron spectrum gave a number of cases where such a dissymmetry seemed to exist. Reese (12) also found triplets and lines of higher separation for several elements which appeared to show the effect. More recently a series of papers has been published by Zeeman (31) comparing the mercury triplets λ5770 and λ5791 by various optical methods. The latter line is distinctly shown to have its red component nearer the central line than is the violet component, while λ5770 remains perfectly symmetrical. The amount of dissymmetry appeared to vary as the square of the field-strength. This confirmed a measurement made about the same time by Gmelin (32) with the echelon grating. A dissymmetry of this sort is always small and difficult of detection. Large dissymmetries are to be classified as abnormal separations. A few lines of such a character occur in the iron and titanium spectra, which will be noted later. Lines of very pronounced dissymmetry were measured by Jack (33) in the spectra of tungsten and molybdenum. Chromium also shows a great number of unsymmetrical separations. Some striking cases were observed by Dufour (34), and many others have been photographed in this laboratory. The theory of coupled electrons, by which Voigt (35) has sought to explain complex separations in general, allows for the occurrence of such dissymmetries.

The magnetic separation of absorption lines, or the "inverse Zeeman effect," has been investigated by a number of observers, as a rule for only a few lines. In such experiments white light is passed through the vapor of a luminous source placed between the poles of a magnet. It was shown by König (36) and Cotton (37) that there is a full correspondence between the effects of the magnetic field for both emission and absorption lines. The splitting of lines in the spectra of sun-spots observed by Hale (38) was thus proved to be due to the action of magnetism by comparing the Zeeman effect for the same lines as produced in the laboratory. The peculiarities in separations of sun-spot lines can thus be studied, as is being done in this laboratory and by Zeeman and Winawer (39) in their investigation of special polarization effects for absorption lines, especially when the light passes at different angles to the magnetic force-lines.

2. Possible Relation Between Zeeman Separation and Pressure Displacement.

A preliminary paper on this subject has been published by the author (40). In the discussion of the present results material will be offered for an extended study to test the hypothesis of a direct connection between the Zeeman effect and the pressure displacement for spectrum lines. That such a relation exists has been strongly advocated by Humphreys (41) in a series of papers which have been summarized (42) by him, together with all other pressure investigations up to the year 1908. Humphreys's hypothesis, briefly stated, is that the part of the atom to which the light impulse is due is a ring of electrons, rotating with a period of the order of the light vibration. Each of the electron rings will then set up a magnetic field of its own. The luminous gas will be in a condition of minimum potential energy when the planes of the rings are parallel and the electrons revolving in the same direction. We must, however, in view of the Zeeman effect, consider that different rings may rotate in opposite directions, and assume merely that the regular condition is a rotation of the electrons in orbits approximately circular, with a tendency for the planes of these to become parallel. The effect of pressure in the surrounding medium will be to bring the rings closer together, thereby altering their mutual induction. If two rings rotating in the same direction are made to approach, the current in each ring will decrease, which means a retardation of the rotating electrons and an increase of period in the corresponding light vibration, resulting in a shift of the spectrum lines toward the red.

If rings of opposite rotation are forced closer together, their motion will be accelerated, resulting in a shift of the spectrum lines to the violet. Assuming that both directions of rotation are present for electrons producing each spectrum line, the general result will be a widening of all lines as the pressure increases, with a prevailing shift of the maximum of each line toward the red. This last is due to the fact that the condensing action of the pressure on rings rotating in the same direction is assisted by the effort of these rings to get into the strongest part of their mutual field; while for oppositely rotating rings the approach is opposed by the magnetic action, so that on the whole the retardation of the period for a given line is greater than the acceleration, and the line, while being widened toward both red and violet, has its maximum intensity moved toward the red.

Another theory, by Richardson (43), opposes the connection of pressure displacement with Zeeman effect. Instead of basing his reasoning on magnetic perturbations, Richardson considers the electron as an oscillator which sets up an alternating electrostatic field in its neighborhood. This field would produce forced vibrations in the electrons belonging to neighboring atoms, an effect increased by pressure in the medium. The electric field produced by the forced vibrations would then react on that of the radiating electrons. The mathematical development gives a change of wave-length proportional to the pressure and toward the red. Worked out numerically with the available data, the electrostatic resonance theory requires values for the pressure displacement many times greater than those observed experimentally. A modified conception of the equilibrium conditions might account for this discrepancy.

Richardson objects to Humphreys's theory largely on the ground that the magnetic disturbances of period would be far too small to account for the observed displacements of lines unless the magnetic field for any atom is greater than that corresponding to saturated iron, which Richardson holds to be an upper limit. This is replied to by Humphreys in a later paper (41d), in which he questions the right to base the possible magnetic intensity of iron atoms upon the properties of iron in large masses, since the permeability and saturation point depend upon many factors of composition and physical condition. Going farther, Humphreys considers an ideal electron ring and deduces an expression for the change of rotation frequency brought about by an external magnetic field H, such as that due to a neighboring electron ring. This is found to give an expression for the change of wave-length $\Delta\lambda$ in the ether vibrations of original wave-length λ which reduces to $\Delta\lambda/H\lambda^2=C$, a constant, which is Preston's law for the Zeeman phenomenon, indicating that the ideal electron ring is very similar in structure to the actual radiating particle. If this similarity be admitted, Humphreys is justified in his next step, which is the substitution of known values in the expression for the change of wave-length of ether vibrations produced by a change in the period of the electron ring. This gives a field-intensity for the rotating ring of 45×10^7, which is about ten thousand times that of the strongest fields used in spectroscopic work. The change in mutual induction by pressing together electron rings having fields of this magnitude may be expected to give shifts of spectrum lines of the order of those measured.

A third theory is that presented by Larmor (44), who treats the electron as a Hertzian doublet in a field of electric force. This field would be altered by any change in the distribution of material particles in the medium such as would result from increased pressure. A molecule approaching a vibrating electron would decrease the rigidity of the ether at that point. A lowering of the ether strain would tend to increase the period of the electron, and it is shown that this might give displacements of the magnitude observed for spectrum lines. A note by Humphreys (41c) points out that several consequences of Larmor's theory agree only to a limited degree with observed facts, although his claim that Larmor's equations should give the amount of displacement inversely proportional to the wave-length is incorrect.

The interacting magnetic atoms of Humphreys seem to provide a very plausible theory, but experimental data have been lacking to show the probability of a connection between the effects of pressure and magnetic field on spectrum lines. Humphreys considers that, in general, lines of large Zeeman separation are strongly displaced by pressure, but admits that there is scanty material on which to base this conclusion. The refusal of banded spectra, notably that of carbon, to show either Zeeman effect or displacement has often been cited as probably resulting from a connection between the two phenomena, and interesting developments on this point have recently been presented. Dufour (45) obtained Zeeman separations for the component lines of the band spectra of the chlorides and fluorides of the alkaline earths, the magnitude of separation being about the same as for line spectra. A short time after, Rossi (46) selected three of these, the fluorides of calcium, strontium, and barium, and obtained distinct pressure shifts for the bands, the shift being of the same order as for line spectra. Comparing his results with those of Dufour, Rossi did not find any general relation between the magnitude of the two effects. Numerous investigations on the Zeeman effect for banded spectra have been made during the past two years, part of which are summarized by Dufour (47), but corresponding results for pressure have not been obtained.

A detailed comparison of Zeeman separation and pressure displacement for the line spectra of iron and titanium will be made in the present paper.

3. Former Investigations of the Zeeman Effect for Iron.

Passing to special investigations on the iron spectrum in which the magnetic separations for certain lines have been described and measured, the first to be mentioned is that of Becquerel and Deslandres (9). In this, 10 lines are given from λ3821 to λ3873, most of them of complex separation. Shortly after, these writers used a stronger field and covered a larger region. This publication (10) gives no measurements, being confined to a description of a few interesting types of lines.

A note by Ames, Earhart, and Reese (11) speaks of the general characteristics of the iron lines between λ3500 and λ4400, with special mention of the type of separation for a few lines. Reese (12) gives measurements of the separation for 23 of the stronger lines in this region, the source being a carbon spark with iron as an impurity. Kent (13) continued the investigation with better equipment, measuring about 90 iron lines between λ 3550 and λ 4550. Special attention was paid to a number of complex lines. Reese had observed that the lines on his plates could be classified as to amount of separation in about the same way that they were classified as to pressure displacement. Kent, with more material available for comparison, found that this relation was not verified.

The paper by Zeeman (30) was concerned chiefly with the question of a dissymmetry of the side components of triplets, as measured from the central line. Hartmann (48) investigated the structure of a number of iron lines with the echelon spectroscope. He did not, however, obtain as good resolution of complex types as was given by the grating method in the present investigation. The most extensive set of measurements thus far published on the iron spectrum is given in the thesis of Mrs. van Bilderbeek (49). These are from photographs made with a concave grating for a magnetic field of 32,040 gausses. Measurements are given for 137 lines between λ2382 and λ4529. Of these lines 55 (40 per cent) are to the violet of the region covered by my photographs; the others are the stronger lines among those given in my tables, and have been of great service in determining the field-strength. As will be noted later, there is an excellent agreement between the two sets of measures for all lines whose components are sharp enough to give measurements of high weight. Besides checking my standard field, the agreement between Mrs. van Bilderbeek's field-value and that which I had obtained by other methods supports the contention in her paper that the field-strengths published by Kent and by Hartmann are both low.

It will thus be seen that several investigations of special regions have been carried out for the iron spectrum with regard to the Zeeman effect. The region covered, however, has not extended beyond about λ4500, with the exception of a few lines in the green examined by Hartmann, leaving nearly three-fourths of the range included in this paper as new territory. For the region from λ3700 to λ4500, which has been covered to some extent by others, the previous investigators have measured only the stronger lines, the description of the character of separation is usually brief or lacking, and the complex separations are but incompletely considered. The range of spectrum covered previously has not been sufficient to draw any conclusions regarding the variation of separation with wave-length, the comparison with pressure effects and other changes of physical condition has not been carried out, and no application has been made of Runge's rule for the commensurability of the distances between components. These points will be handled in the present paper as fully as the material will permit.*

4. Former Investigations of the Zeeman Effect for Titanium.

A set of measurements was published by Purvis (50) for many of the stronger lines of titanium from λ 2800 to λ 5000. The majority of these are in the ultra-violet, 86 lines being measured in the region covered by my tables. Three violet triplets were measured by Reese (12). A former paper by the author (51) gave descriptions and measurements for 291 lines between λ 3900 and λ 6600. These were made from the first set of plates taken in this laboratory, the first and second orders of the 13-foot (4 m) spectrograph being used, with a field of 12,500 gausses. The data for the present paper were compiled from a much more extensive set of plates, taken with higher dispersion and stronger field, the gain in all points being so great that these measures may be taken as superseding the previous ones. A still earlier paper by the author (52) gave preliminary measures of some titanium and iron lines in a discussion of the character of their separation in the laboratory as compared to that observed in sun-spot spectra.

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* Note added January, 1912: A dissertation by Immina Maria Graftdijk on ***Magnetische Splitsing van het Nikkel- en Kobalt-Spectrum en van het Ijzer-Spectrum*** (Amsterdam, 1911) has just been received. Measurements are given for 38 of the stronger iron lines between λ 4300 and λ 6500 for a field of 32,040 gausses. The measured separations of triplet lines agree in general very closely with those presented in this paper. The only notable discrepancies are for a few complex lines where a large difference in field necessarily alters the appearance of the components which are measured.

APPARATUS AND METHODS.

1. Spark Apparatus.

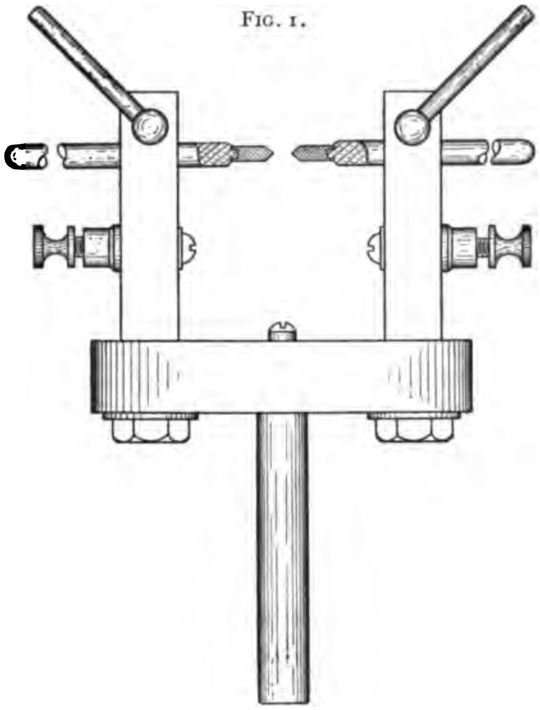
The source of light used in all of the work was a spark discharge from a 5-kw transformer made according to special design by the Peerless Electric Company, of Warren, Ohio. The coils of this transformer are immersed in the best moisture-free oil and contained in a cylindrical iron tank 83 cm in diameter and 125 cm high. The primary and secondary leads are passed through the flat top of the transformer, on which is a large knife switch for the regulation of the secondary voltage. The bar of this switch forms the radius of a circle, one end being pivoted, while the other end fits into any one of a series of jaws along the circumference of the circle. The connections with the transformer coils are such that the secondary voltage may be 10, 20, 40, 80, 160, 320, or 640 times the impressed primary voltage, according to which jaw the bar of the switch is fitted into. Thus with 100 volts on the primary the secondary voltage is 1,000, 2,000, 4,000, 8,000, 16,000, 32,000, or 64,000, according to the connection. The use of a rheostat in the primary circuit to regulate the impressed voltage will obviously give any secondary potential desired up to 64,000 volts. The adjustable rheostat used is one capable of carrying heavy currents continuously. It is composed of sheets of tin cut into strips 1 cm wide by cutting almost across the sheet first from one side and then from the other. The sheets of strips thus made are mounted vertically against strips of asbestos fastened to a wooden frame, the distance between successive sheets being sufficient to provide air circulation for cooling. Copper wires soldered to the tin strips at the proper intervals lead to knife switches on the top of the rheostat frame. Various combinations of these switches place parts of the tin resistance in series or parallel, and permit the resistance to be reduced by short steps until all is out. One switch may be connected to an external resistance, thus allowing the latter to be connected in series with any part of the tin resistance for fine adjustment of the rheostat. A bank of twenty-four 32-cp incandescent lamps in parallel is usually used in this branch.

The primary current is supplied at about 104 volts from one side of the three-phase connection of a 15-kw transformer. This transformer and one similar to it are mounted in the transformer room of the laboratory, fed by 2200 volts from the lines of the Southern California Edison Company, and are used together to supply the 208-volt three-phase current for the D.C. motor-generator set which furnishes current to the electro-magnet.

Two glass-plate condensers were used for the spark circuit during the series of experiments. The more efficient one, used in taking the later photographs, is built up of 16 sheets of plate glass, of area 61 × 66 cm, and thickness 5.5 to 6.0 mm, laid horizontally in a strong, copper-lined wooden tank. Between the glass plates and at the top and bottom of the pile are sheets of copper, 17 in number, each 0.9 mm in thickness and with an area of 3330 sq cm, one side of each sheet having a tongue 2.5 cm long projecting beyond the glass plates for the connection, while the plates immediately above and below are cut away so as not to reduce the insulation at this point. Around the other three sides the copper is cut so as to come 2.5 cm inside the edge of the glass plates. This arrangement, together with the form in which the copper is cut on the fourth side where the tongues project, insures a distance of 5.7 cm along the glass from the edge of one copper plate to the edge of the next. The condenser plates are separated from the copper lining of the tank by a wood flooring 2.5 cm thick and held in place by a wooden box inside the tank. A thick copper wire is soldered to each of the tongues coming from the copper plates and the other end of the wire connected to a binding post set in a plate of fiber extending across the width of the tank, 7.5 cm below the top. This fiber plate was at first placed level with the top, as shown in the photograph of the laboratory (Plate I). This condenser is entirely immersed in the best transformer oil, which fills the tank up to about 5 mm above the fiber plate, thus insulating the condenser plates and also the binding posts, the screw tops of the latter projecting from the oil to receive the wires connecting them in any desired combination to the discharge circuit, so that the whole or any part of the condenser may be used. An adjustable spark-gap between the nearer binding posts on each side protects the condenser against too long a spark in the circuit which might cause the glass to be punctured. Connecting wires from the two central binding posts are inclosed in thick glass tubes which pass through a second fiber plate directly above the first and level with the top of the tank to the high tension wires supported by glass insulators and extending across the laboratory below the ceiling. A wooden cover fits into the top of the tank and protects all parts of the condenser from dust. The leads from the transformer pass to the overhead wires and other leads drop down to any piece of apparatus under the wires, so that the heavy condenser can remain permanently in its place.

In addition to the condenser, the circuit from the transformer contains a self-induction spool and spark gap in series with the spark under observation. Several self-induction coils are available, but the one regularly used consists of 207 turns of insulated copper wire wound on a wooden cylinder 132 cm long and 13 cm in diameter. A sliding contact may be moved to any point along the spool so as to include any desired portion of the self-induction.

Fig. 1.



The terminals for the spark on which the magnetic field acts require different handling according as the substance under examination is magnetic or not. In the experiments with titanium, small pieces of the substance known as "cast titanium," obtained from Eimer and Amend of New York, were held in small brass clamps, the vertical rods of which passed through larger horizontal brass pieces set in a thick piece of fiber, through the middle of which a brass rod passed and fitted into a clamp, movable up and down on a support attached to the base of the electro-magnet.

When iron terminals were used it was necessary that they be held rigidly in place on account of the attraction of the magnet. In all cases small cylinders of Norway iron were screwed on the end of brass rods. The size of the iron tips varied somewhat according to the kind of spark desired and the width of the magnetic gap used. Those most generally used with a strong field were 3.5 mm in diameter and about 10 mm long. In the earlier work the iron-tipped brass rods were held in a hard-wood frame composed of two vertical rings held apart by four horizontal pieces. The wooden rings fitted over the magnet core, against the face of each coil, while the brass rods passed with some friction through two of the horizontal wood pieces at opposite ends of the diameter of the rings. A better holder for iron terminals was devised later. This is shown in Fig. 1 and is a modification of that used for non-magnetic substances, the parts being much more rigid. The rod of 6 mm diameter to which the iron tip is screwed passes through a square brass rod 16 mm in thickness, having a saw-cut from the hole out to the end. A screw at right angles to this saw-cut, worked with a bar, serves to clamp the rod so firmly that the magnet does not move it. As the column supporting the holder is screwed to the base of the magnet, all parts could be clamped so firmly that the iron tips were held exactly in place.

The spark length for both iron and titanium was usually short on account of the proximity of the magnet poles and the tendency of the spark to jump to these. With iron terminals, particles were given off rapidly by the strong transformer discharge and it was necessary to clean these off every few minutes and also to file off the oxide from the iron tip. Titanium terminals wore away rapidly, owing to disintegration of the metal, and the oxide also needed to be removed frequently if the brightest discharge was to be obtained. The short spark gap necessitated an auxiliary gap in series, as otherwise the discharge was not sufficiently disruptive to avoid melting the terminals. This auxiliary gap was a simple affair of brass mounted on fiber.

When using the spark, the various parts of the secondary circuit, as well as the step-up connection and the current in the primary, were adjusted to give the sort of spark desired. In this investigation self-induction has been used in the spark circuit somewhat sparingly, since on the majority of the photographs it was necessary to obtain the fainter lines of sufficient strength for accurate measurement. Self-induction in the spark circuit sharpens the Zeeman components in about the same degree that it sharpens the lines of the regular spark spectrum, but the brightness of the spark is greatly diminished at the same time, an effect only partially due to the decrease in intensity of the enhanced lines. The weaker lines as a whole, especially the faint and diffuse lines of iron, are so reduced by self-induction that very long exposures are required to bring them out. A compromise must be made, since in exposures running many hours, especially for more than one day, there is risk of instrumental disturbances. The method followed was to use the spark with rather high self-induction for one or more photographs of any region containing strong lines, and especially enhanced lines, for which moderate exposure time was sufficient, then to use small self-induction for photographs in which as many of the weak lines as possible were desired. The loss of sharpness in such cases was counteracted as far as possible by the use of a narrow slit and by selecting the kind of plate and developer which would give the sharpest definition and at the same time show the lines.

2. The Electro-Magnet.

This apparatus is of the Du Bois half-ring type, made by Hartmann and Braun of Frankfort. It is shown (in its present state, after being rewound) in the photograph of the laboratory (Plate I). The coils, as used until recently, were each wound with 1250 turns of No. 9 wire (diameter =3.0 mm). They are clamped to a horizontal iron base which completes the magnetic circuit. The magnetic gap is varied by moving the coils upon this base, which is itself supported by three legs on an iron plate. A hole in the center of this plate fits over a pivot in the middle of a round iron table, the ends of the plate resting on a planed ring which forms the rim of the table. The magnet can thus be turned in any desired direction by rotating the base-plate upon the planed ring of the table. The magnet rests upon a cement pier 60 cm square and 82 cm high. The core of each magnet coil is pierced by a horizontal hole 17.5 mm in diameter for the transmission of light along the lines of magnetic force. These holes are filled with cylindrical iron rods when such an axial opening is not needed.

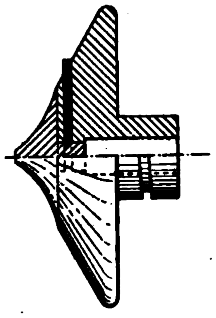
A variety of pole-pieces was used for the magnet according to the way in which the spark terminals were arranged and the directions in which the light was to be taken. Into each vertical face of the magnet core is screwed the first section of the pole-piece, a truncated cone of soft iron 16.5 mm thick, whose double angle is 112°. The small end of this cone is a circular plane surface 39 mm in diameter. To this circular face was fastened a pole tip of one of the following forms, each of which has a double angle equal to that of the truncated cone just described.

(*a*) For the observation of the light from the iron spark parallel to the lines of force, the magnet poles themselves were used as spark terminals in some of the earlier experiments. In this arrangement the faces of the tips were circular, of 6 mm diameter. One pole was left solid and the other pierced with a hole 3 mm in diameter, the spark being viewed through the tubular hole in the core. The pole-tips were each insulated from the core by mica plates and held in place by fiber screws. The method gave trouble, not only from the occasional breaking down of the insulation, but from the fact that the spark did not stay in front of the hole in the pole-piece. It had the advantage, however, that the field was not affected by the introduction of extra iron as spark terminals.

(*b*) A stronger light from the spark was obtained for observation along the axis by not insulating the pole-tips, using one solid and the other pierced as in (*a*), with the spark between iron tips at the ends of brass rods held vertically between the magnet poles by means of a wooden frame or the brass and fiber holder described on p. 10. Titanium terminals were held in the simple clamp described above. This worked well for getting the "longitudinal effect" (*n*-component) without the introduction of a Nicol prism in the optical system. Such an end-on arrangement is of course necessary for the study of the circular polarization of Zeeman components. However, for general work in measuring the separation of components, this method has the disadvantage that there is a considerable increase of field-intensity close to the magnet poles, amounting with some gaps to 25 per cent, as well as an inequality at the two poles resulting from one of them being pierced, so that the sharpness of the Zeeman components is not all that could be wished.

(*c*) The most useful method, and that used (with varying shapes of the pole-tips) for almost all of the best observations, was to set the magnet at right angles to the direction at which the light was observed, use both pole-pieces solid, and separate the light by means of a Nicol prism over the slit into that vibrating in a plane at right angles to the magnetic force-lines, or parallel to these. This arrangement made it possible to photograph successively the Zeeman components given respectively by vibrations perpendicular and parallel to the force-lines by turning the Nicol prism through 90°, leaving the magnet unchanged. Furthermore, by projecting the image so that only the light from that part of the spark midway between the magnet pole-pieces falls upon the slit of the spectrograph, the change of field near the pole-pieces does not disturb the definition of the Zeeman components. Even if the slit is long enough so that parts of the image come from regions of different field-strength, the spectrograph, not being astigmatic, shows merely a wider separation toward the ends of the components, the sharpness not being affected, so that accurate measurements may be made by selecting the narrowest portion of the separation.

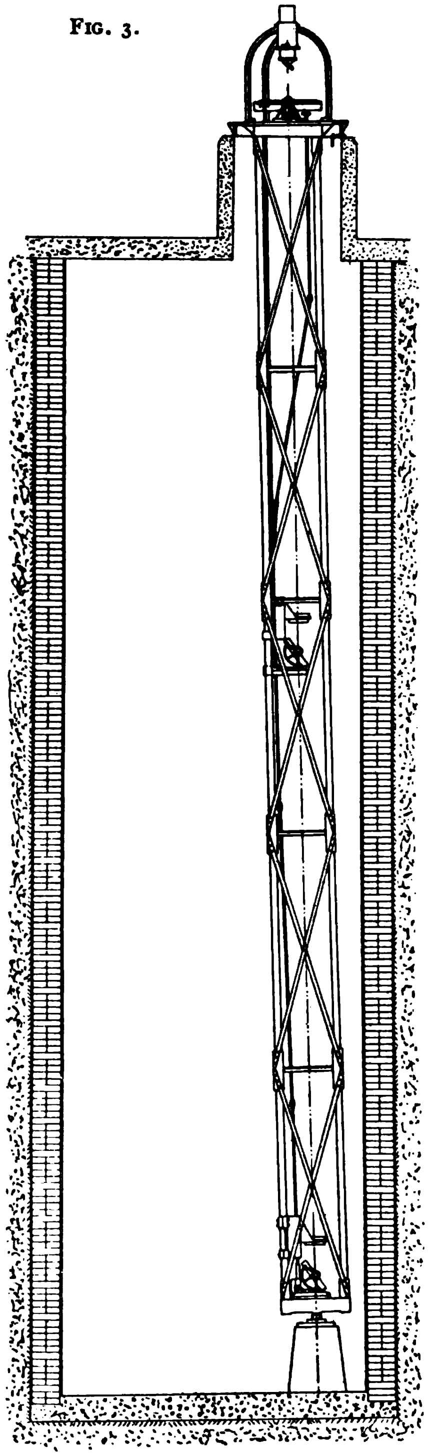
FIG. 2.



Three forms of magnet pole-tips were used with this arrangement. In the first, the conical tips ended in circular faces 6 mm in diameter. This was used for most of the work on iron and for the earlier work on titanium. With titanium, however, the pieces of metal were irregular in shape and often rather large, so that with a short magnetic gap it was difficult to bring the terminals close enough together to avoid sparking to the magnet pole-pieces. The later and best set of titanium plates was taken with pole-pieces somewhat chisel-shaped, made by milling out opposite sides of a conical tip of 12 mm face to a thickness of 1.5 mm. The thin ends were then placed parallel to each other and in a line with the beam of light passing to the slit. This gave a very uniform field for the light of the thick spark, part of the vapor of which might otherwise have gotten into weak portions of the field. Probably the best design is a modification of that just described, in which the chisel edge was left 3 mm in thickness and 12 mm long, and not so deeply milled as before. This form of tip gave a very strong field and a gap of 6 mm could be used without difficulty. The drawing in Fig. 2 shows this design, with which a number of the later iron spectra were taken.

A current of 10 to 12 amperes from a 12.5-kw generator was generally used for the magnet circuit. 15 amperes could be used for runs of two or three hours, but the magnet rapidly became heated. This current was almost sufficient to saturate the core and a larger current gave but a small increase of field. The heating of the core by long-continued runs, even at 10 amperes, was considerable in warm weather, when the two electric fans used to blow the sparks, and which also played on the magnet, exerted little cooling effect. Almost at the close of this investigation a very efficient means of cooling the core was devised. Injuries to the insulation of the wire made it necessary to rewind both magnet coils. When the cores were laid bare, a spiral of soft copper tubing of 6 mm outside diameter and 4 mm bore was wound around each core next to the iron. Strips of "5000-volt linen" were wound over the spiral as insulating material, the face-plates at the ends of the coil being protected by ebonite sheets, and 1300 turns of wire were wound on each coil, the extra 100 turns on the two coils more than compensating for the magnetic leakage caused by introducing the copper spiral. With a stream of water flowing through the spiral, the core remains perfectly cool and a current of 14 amperes may be used without serious heating of the wire. This improvement has given an increase of field of about 25 per cent over what could previously be used for long runs with the same magnetic gap.

FIG. 3.



The current is controlled by means of two Ruhstrat sliding resistances in parallel and is read to 0.1 ampere by a Weston millivoltmeter with shunt used as an ammeter.

3. THE SPECTROGRAPH.

The spectrograph which was used in this investigation was described briefly in the general account of the Pasadena laboratory published in 1908 (53). It is of the Littrow or autocollimating type, placed vertically in a well 30 feet (9.1 m) deep. The design of this spectrograph was worked out during the early solar investigations on Mount Wilson and the first instrument in the observatory equipment was made by William Gaertner of Chicago, and has been in use for over three years as a part of the 60-foot tower telescope on Mount Wilson. A description was published in *Contributions from the Mount Wilson Solar Observatory* (54). When the physical laboratory in Pasadena was equipped in 1908, an exact duplicate of the mountain spectrograph was obtained from Gaertner, with the addition of holders for lens and plane grating to give a focal length of 13 feet (4 m) when desired, as well as the full focal length of 30 feet (9.1 m).

The details of the mounting of the spectrograph can be seen from the drawing in Fig. 3 and from the photograph of the upper end (Plate II). The well is made water-proof with a lining of brick, several layers of tarred building paper, and cement plaster, the dimensions being 30 feet (9.1 m) below the floor of the laboratory and 8.5 feet (2.6 m) in diameter. Since the well was thoroughly dried out, no moisture has appeared to come through the walls. The cover of the well is of reinforced concrete, with two openings. A circular opening at the east side is inclosed by a cement ring 70 cm high and 110 cm outside diameter, which supports the metal top of the spectrograph. Entrance to the well is provided for by an opening at the south side closed by a wooden cover, from which a vertical iron ladder leads to the bottom. Attached to the iron ladder is a stout wood platform, at such height that the parts of the spectrograph for the 13 feet (4 m) focus can be conveniently adjusted.

The spectrograph consists essentially of a skeleton steel frame 50 cm square, at the top of which is a circular cast-iron plate on which is the slit and holder for the photographic plate, while below, the objectives and gratings are supported in the steel frame at the proper levels for the focal lengths desired. The weight of the frame is supported by a concrete pier placed at the bottom of the well. This pier carries an iron plate with a spherical cavity, into which fits a lubricated hemisphere on the lower end of the spectrograph frame. The iron plate at the upper end of the instrument fits loosely inside a circular iron casting imbedded in the concrete ring already described. The whole spectrograph turns easily about a vertical axis by means of a gear and pinion in the outer casting. A simple clamping device holds the instrument against accidental turning when in use.

The slit of the spectrograph, 51 mm long, is placed on the end of a brass tube sliding within another tube attached to the iron top. The divided head regulating the width of slit is graduated to read 0.025 mm. For strong light sources, a slit width of 0.075 mm was regularly used. When the 30-foot arrangement is in use, the light passes from the slit to an 8-inch (20.3 cm) visually corrected objective by Brashear, which lies horizontally in a holder capable of being moved vertically for focusing by turning a rod passing to the top of the spectrograph and rotated by a hand-wheel. A metal box to hold a plane grating is just below the lens. A rod, geared to the grating box and passing above to a second wheel at the top of the instrument, permits the rotation of the grating about a horizontal axis to obtain the order or region of spectrum desired. Scales which show the position of the lens and the inclination of the grating can be read by a small telescope at the top of the instrument when illuminated by incandescent lamps turned on from above. The light reflected by the grating passes again through the lens and the spectrum is brought to a focus above, the middle of the photographic plate lying in the same plane as the slit. The holder carrying the plate rests in an iron frame supported at its center so that by tilting the plate-holder good focus can usually be obtained over the whole of the plate, which is 17 inches (43 cm) long and 3.62 inches (9.2 cm) wide. The plate-holder can also be moved parallel to itself by means of a rack and pinion to permit the photographing of successive spectra. Two shutters, sliding horizontally, are placed 7.5 mm below the plate and can be adjusted to shut out all light except the strip of spectrum, the width of which is regulated by the length of slit used. Light reflected from the lens surfaces would reach the plate were it not for these shutters and for the fact that a narrow bar is laid across the center of the lens so as to cut off the reflected rays which would enter through the opening of the shutters. With the 30-foot focal length, a slight inclination of the objective removed the reflections without appreciably affecting the definition.

The arrangement of lens and grating to give the spectrograph a focal length of 13 feet (4 m) follows the plan of that for the longer focus. The movements of lens and grating are regulated by the same rods which control those below. The grating-holder may be moved over to the side of the steel frame and the lens-holder swung back out of the way when the 30-foot arrangement is desired.

The two plane gratings used during the investigation were a Rowland grating 12.5 cm long and 9 cm wide, having 568 lines to the millimeter and a Michelson grating 19 cm long by 7.2 cm wide, having 500 lines per mm. The former was used with the 13-foot arrangement for the majority of the plates. The Michelson grating was obtained near the end of the investigation and a number of the later plates were taken with this, which was adjusted for the 30-foot focus. While longer exposure must be used with the longer focus, the large scale is very desirable and the field is much flatter, so that as a rule the whole length of spectrum over a 17-inch (43 cm) plate can be obtained in fair focus, even in the first order. For very weak light-sources, however, the 13-foot arrangement often gives better results, as there may be unavoidable changes in either the source or the spectrograph if the exposure is greatly prolonged.

The scales of the photographs for the two focal lengths and the several orders used in this work are approximately as shown in the small table on the following page, there being a variation in the second decimal place according to the part of the spectrum observed.

Other important features of the spectrograph are the occulting plate of the slit, the mirror support, and the polarizing apparatus. Plate II shows the form of the occulting plate. It is of brass, dull silver-plated, and supported on four pins screwed into the top of the spectrograph, so that it is entirely free from the slit, and about 2 mm above the latter. By moving the V-shaped opening *a*, by means of the rack and pinion, any length of slit up to 11 mm may be obtained. A further movement brings the double opening *b*, whose size may be adjusted by the sliding plate *c*, over the slit. By a proper setting of the scale *d*, a double comparison spectrum can thus be placed outside that made with the opening *a* without risk of instrumental displacement, since the plate-holder and all essential parts of the spectrograph are left untouched.

Plate II shows the arrangement of the mirror by which the light coming horizontally from any piece of apparatus in the laboratory is reflected to the slit of the spectrograph. The holder for the mirror, which is of plate glass 12.5 cm in diameter, silvered on its front surface, can be turned about a horizontal axis, and is supported at the lower end of a brass cylinder. This cylinder can either rotate or move up and down inside a stationary cylinder held in position by three curved iron supports which are screwed to the top of the spectrograph. The mirror may thus be placed in any position necessary to direct the beam into the instrument. As the mirror can be turned in any direction independently of the spectrograph, we may have any desired orientation of the slit with respect to the light source, which is usually out of the question with a spectrograph mounted horizontally. This is a very great advantage in an instrument free from astigmatism. For the Zeeman photographs the slit was regularly used parallel to the lines of force of the magnet. In photographing arc and spark spectra in general, it is desirable to use the slit sometimes parallel, sometimes perpendicular to the direction of discharge in the image projected upon it.

Focus.	Order.	Ångströms per mm.
13 foot	Second	2.05
13 foot	Third	1.35
30 foot	First	1.92
30 foot	Second	0.95
30 foot	Third	0.60
30 foot	Fourth	0.45

The Nicol prism, by which the light polarized in one plane is transmitted to the slit, is held on a metal platform 3.5 cm above the slit. The Nicol prism which has been used thus far was loaned by Director Stratton of the National Bureau of Standards. The diagonals of the face are 25 and 30 mm and the prism is 6.5 cm long. It is held in a brass cylinder having a graduated circle by which the Nicol can be set at any desired angle to the plane of polarization of the incident light. A second platform can be placed above the Nicol to hold a Fresnel rhomb when this is desired for the study of circular polarization.

Since the beam passing through the Nicol is displaced parallel to itself, when the prism is rotated 90° to transmit the other Zeeman component the image does not remain on the slit. The image is then brought back by moving the focusing lens, a simple glass lens of 58.4 cm focal length and 10 cm diameter. After such a change, it was always noted whether the grating was well centered in the beam of light, which usually had at least three times the diameter of the spectrograph objective. Although small movements of a focusing lens of the focal length used produce very slight changes in the direction of the beam to the grating, still care was taken never to move the lens when an instrumental displacement of the spectrum lines could have any disturbing effect. After an exposure with the magnetic field, the only change before starting the exposure for the spark without field was to move the occulting plate above the slit, so that the comparison spectrum would be on each side of the spectrum taken with the field. The light source thus remained unchanged in position, and all parts of the optical system as well as the photographic plate were left untouched.

The spectrograph remains in adjustment for longer periods probably than with any mounting other than the vertical arrangement in a well. The temperature change at the bottom of the well is entirely negligible during short periods of time. A recent test showed that during three months in which temperature variations of over 15° C were experienced in the laboratory, a thermometer placed beside the grating rose very gradually from 18°.6 to 19°.0 C. During this time the lights were frequently turned on to read the adjustment scales, and there were occasional visits by observers to the bottom of the well. Mechanical vibrations are more disturbing. It has been necessary to close the driveway beside the laboratory during exposures with the spectrograph, and to take care that no machinery be used which would transmit a vibration to the spectrograph mounting.

4. PHOTOGRAPHIC METHODS.

The requirements as to photographic plates in an investigation of this sort are to some extent conflicting. Speed, a fairly fine grain, good latitude, so that weak lines may be obtained without serious over-exposure of the stronger ones, together with enough contrast to give sharply defined lines, are elements not easily combined in one plate. A number of plates have been tried, including the Lumière "Sigma," the Seed "Gilt Edge 27," "23," and "Process," the Cramer "Crown" and "Inst. Isochromatic." Each kind of plate will give superior effects for a certain type of line; but in general I have obtained the best results for the work from the Seed "Gilt Edge 27" for the blue end of the spectrum as far as about λ4600, and from there on into the red from the same plate bathed with the solution of pinacyanol, pinaverdol, and homocol recommended by Wallace (55). This plate is the best adapted of those I have tried in regard to doing justice to all classes of lines. It is a fast plate without an objectionably coarse grain. The latitude is good. In the case of lines of complex Zeeman separation, a plate with more contrast will often fail to show weak components very close to stronger ones.

A properly chosen developer will sharpen the lines to a great extent, avoiding troublesome shading off from the central maximum. After trying several solutions, I have preferred a hydroquinone developer giving strong contrast, due to Mr. Wallace, but not published so far as I know. The proportions are as follows, using equal parts of A and B:

Solution A:		*Solution B:*	
Water	48 oz.	Water	48 oz.
Hydroquinone	640 grains	Carbonate soda (anhydrous)	1 oz.
Sulphite soda (anhydrous)	1 oz.	Carbonate potassium (anhydrous)	4 oz.
Sulphuric acid (conc.)	30 drops	Bromide potassium	¼ oz.

This developer does not stain the plates, even when warm. Development was usually carried to the point where chemical fog sets in. This comes on slowly, and the solution is as efficient in bringing up weak images as any I have tried. When used at 20° C a bathed plate is usually fully developed in 6 to 7 minutes. Some very good photographs were obtained for the region λ5200 to λ5500 by the use of the Cramer "Inst. Isochromatic"; but it was found best to soften its contrast by the use of a metol-hydroquinone developer. For the region λ4800 to λ5100, where the "Isochromatic" is weak, as well as for the whole of the orange and red, the action of the bathed "27" has been unsurpassed by any plate used in these experiments.

5. MEASUREMENT OF MAGNETIC FIELD.

The accurate measurement of field-strength presented some difficulties in the case of iron on account of the use of metallic terminals for the spark. The field for titanium was more easily obtained, and was based on direct measurements by a bismuth spiral. This instrument was obtained from Hartmann and Braun, but instead of using the regular formula for temperature correction, the spiral was sent to the National Bureau of Standards and there calibrated to provide a series of curves for the variation of field-strength with change of resistance for temperatures of 15°, 20°, 25°, 30,° and 35° C. When used at intermediate temperatures the interpolation was simple. The resistance in and out of the field was measured with a Kohlrausch bridge.

A set of plates of the titanium spectrum, extending over the whole region investigated, was taken with the magnetic field as nearly the same as possible. All parts of the magnet were left unchanged and the same current was used throughout. By check measurements with the bismuth spiral and by comparison of plates which overlapped enough to measure some of the same lines on both, it appeared that a field-strength of 17,500 gausses was maintained for this set with a variation no greater than 200 gausses. Other photographs taken to supplement the measurement of certain regions had their values reduced to correspond to a field-strength of 17,500 by comparison of the separations of sharply defined lines.

For the iron spectrum it is well known that indirect methods must be used to determine the field-strength, since the use of iron spark terminals distorts the field to such an extent that any object as large as the bismuth spiral or an exploring coil for the ballistic method will not give true values for the field to which the spark vapor is subjected. It may be that the iron vapor, when sufficiently dense, has an appreciable permeability of its own. There is, however, no evidence on this point.

The plates for the iron spectrum were taken at intervals extending over a year, during which various changes were made in the experimental arrangements which involved changes in the magnetic field. However, a considerable region in the blue and violet was photographed with the same field, and the publication of Mrs. van Bilderbeek (49) gave an opportunity to make a comparison with her values. In her work some photographs were taken using a spark with one iron and one zinc terminal, thus obtaining the zinc triplet λ4680.317, as well as some iron lines in that region. Weiss and Cotton (20) by a series of very careful measurements obtained the relation $\Delta\lambda/H\lambda^2 = 1.875 \times 10^{-4}$ for the separation of the outer components of this triplet, from which Mrs. van Bilderbeek deduced the value 32,040 gausses for the standard field which she used when iron terminals alone were employed. I was able to select from my list 33 lines between the limits λ3700 and λ4400, which are also given in Mrs. van Bilderbeek's table, in nearly all cases clear triplets, for which my measurements are of high weight. The ratio between Mrs. van Bilderbeek's values and mine for these lines was in every case very close to 2, the greatest deviation being given by the value 2.14. The mean ratio for the lines is 2.01, giving a value of 15,940 gausses for the field used by me in photographing the iron spectrum. This is in very satisfactory agreement with a value which I had already determined by photographing the strong line λ4383.720 as given by a spark between carbon terminals on which a little iron solution was placed in a field measured by the bismuth spiral as 17,600, and comparing the separation with that of the components of the same line very sharply photographed with iron terminals used in the standard field. Exactly the same value was given by comparing the separation of λ4383.720 in two photographs, one with iron poles, the other in which the line came up as an impurity in a titanium photograph taken with the standard titanium field of 17,500. Assuming that the value of the field for iron was established by the other measurements, this last test gave an excellent check on the standard field for titanium, which would otherwise depend on the measurement with the bismuth spiral. It would seem then that the value of 16,000 gausses can be safely taken for the standard iron field with an error less than 1 per cent. A considerable number of photographs for both iron and titanium were made with fields close to 20,000 gausses, sometimes slightly higher, but the measurements were reduced to correspond to fields of 16,000 and 17,500, respectively.

A similar system of checking field-strengths was applied for the region to the red of λ4400. A spark was used with one terminal of iron and the other of brass. Two photographs were taken in which the zinc triplet λ4680.317 appeared as well as a number of iron lines, among them the wide and sharp triplet λ4878.407. Using the value of Weiss and Cotton, the field-strength for the measured separation of this iron line (20,360 gausses for $\Delta\lambda = 1.389$ Å) was deduced. Spark terminals of the same kind with all parts of the magnet unchanged were then used for a series of photographs covering the iron spectrum as far as λ6700. The field was thus kept as nearly constant as possible, and by comparing the separations of iron lines with this known field with those on former plates taken with various fields, it was possible to reduce all values for the iron spectrum to the standard field of 16,000.

6. Methods of Measurement and Reduction.

The measurement of the earlier plates was carried out by Miss Wickham, while the later plates were measured by Miss Griffin. The machine used was a small Gaertner comparator having a range of 8 cm, the divided head reading to 0.001 mm. The process of measurement included the identification of lines, the determination of the reduction factor for the portion of the plate under examination and the measurement of the separation of the Zeeman components.

Various tables were used in the identification of lines. For the iron spectrum the tables of Kayser and Runge (56) for the iron arc were supplemented by those of Exner and Haschek (57) for the spark, also by the list of enhanced lines given by Lockyer (58) and by plates of the arc and spark spectra of iron taken in this laboratory. For the titanium spectrum the tables and charts of Hasselberg (59) were useful as far as λ 5900. This was supplemented for the red end by the measures of arc lines by Fiebig (60). The spark tables of Exner and Haschek and of Lockyer were used as for iron. The identifications of solar lines in Rowland's Tables are in most cases so close to the values in the tables of arc and spark spectra that there is no doubt of the correspondence of the lines. The wave-lengths given in this publication are entirely on the Rowland system.

The chart of the iron arc spectrum by Buisson and Fabry (61) was of great assistance in the approximate identification of lines, the scale being almost the same as that of my plates taken in the third order with the 13-foot focal length. In addition to using this chart for the iron spectrum, it served also for titanium when used in conjunction with a set of plates which I made of the spectra of the titanium spark and iron arc side by side.

The definitive identification of lines was in the usual way by measurement from neighboring lines whose identity was certain. On account of the incompleteness of the general tables of spectra for the red region, a few lines are entered in my titanium table which may belong to other substances. Some of these, in all probability, are lines given stronger in the spark than in the arc, which explains their absence from Fiebig's list. The doubtful origin of such lines is indicated in the column headed "Remarks."

The spectrum given by the plane grating spectrograph not being quite normal, the reduction factor of the plate, expressed in Ångström units per millimeter, was determined at intervals usually of 2 to 3 cm. The change in the factor between successive determinations was thus almost always less than 5 in the third decimal place. This factor was multiplied by the distance in millimeters between the Zeeman components, which was the mean of at least four differential measurements taken alternately right and left, setting first on one, then on the other of the components whose separation was desired. The accuracy of setting on first-class lines was usually well within 0.005 mm. From such lines there are all gradations up to those for which the measurements recorded can be taken only as indicating the order of magnitude of the separation. Frequently a line has its components on one side blended with those of an adjacent line. In such a case it is usually possible to make a more or less accurate measurement of half the separation by measuring from the clear component to the no-field line which was always photographed in juxtaposition. The accuracy of measurement will be discussed further in the explanation of the tables when the weight of measurements is considered.

After measurement by a member of the Computing Division each plate was carefully gone over by the author. In this examination the identification of lines was checked, the character of the separation and weight of the measurement as determined by the quality of the line were decided upon, and many check measurements with the machine were made, including all measures for determination of the magnetic field by a comparison of the separation of lines on different plates.

EXPLANATION OF THE TABLES.

1. Wave-lengths.

The wave-lengths given in the first column are on the Rowland system. The methods of identification and the tables used have been treated in the preceding section.

2. Intensity.

This column is intended to give an approximate value of the intensity of the lines in the spark spectrum. The numbers are taken (with occasional modifications) from the tables of Exner and Haschek for the spark spectrum as far as λ4700, beyond which the intensities were estimated on the same scale from my plates. Weak lines are graded "1" on this scale, but there is considerable variation in the strength of lines which are given this value. For the purposes of this paper, this grading of intensities is sufficient.

3. Character of Separation.

In this column is described the type of separation of each line when the *n*- and *p*-components* are combined, as is the case when the light of the spark is observed at right angles to the magnetic force-lines without Nicol or other apparatus to separate the light vibrating in the two directions. Thus in the reproductions the two portions of each spectrum showing the effect of the magnetic field should be superposed to give the appearance of the line as described in this column.

The description gives the best judgment of the type of separation that can be made from the photographs. It must be considered in connection with the measured separation and widening of components given in the columns for Δλ of the *n*- and *p*-components, and is usually made clear by these. Frequently a supplementary remark is needed in the case of complex lines.

A line designated as triple has its one *p*- and two *n*-components of sufficient sharpness to give no indication that any of them are compound. Since the Zeeman components follow to some extent the general character of the spectrum line, when a line is itself wide and diffuse, its components may be simple and still not so sharp as those of lines which do not tend to diffuseness. The proximity of the no-field line on the plate aids in the judgment of such cases, but some of them are uncertain at the best. The tendency of some lines to reverse is very disturbing in this connection, since it is very difficult to obtain such lines with really sharp components. Several iron lines between λ3700 and λ3900, which give wide reversals in the arc and spark between iron terminals, can be made to show the Zeeman components also reversed, by the use of a strongly condensed spark, so that a triplet appears as a sextuplet. To decide such cases it was necessary to make special photographs, using much self-induction and also with carbon terminals containing a little iron. The titanium photographs were also useful in this connection, since the titanium used contained enough iron to give the stronger iron lines which appear with sharp components under such conditions.

The interrogation point is very freely used to indicate that the line is probably of the character given, though not clearly shown to be so on the plates. The reason for doubt is usually given in the columns for Δλ. Thus "triple?" means that the *p*-component is slightly widened so that it may not be simple, but still the widening may be explained by the strength of the component or by the fact that the line

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* *n* and *p* are used throughout this paper as abbreviations of "normal" and "parallel." *n* denotes the Zeeman components given by light vibrations in a plane at right angles to the lines of magnetic force, and *p* those given by vibrations parallel to the force-lines. The symbols correspond to the letters *s* and *p* regularly used in German publications.

itself is slightly diffuse, which may account for the lack of sharpness in the components. "Quadruple?" means that the two *n*-components are fairly sharp, but the *p*-component is probably double. A doubtful quintuplet will usually have five components measurable, with indications that others are possibly present. Doubtful sextuplets are very common. As a rule such a line has its two *n*-components widened so that there are probably two pairs, while the *p*-component is either distinctly double, or unresolved and considerably widened. The decision between doubtful sextuplets and septuplets is frequently difficult and often quite uncertain. The *p*-component in such cases is not resolved, but the character of its widening will often show whether it is double or triple. A widening with strong central maximum means usually three *p*-components, but there may be five. Such a line, if it has two widened *n*-components, is classed as a probable septuplet. Octuplets and lines of higher separation are classified in a similar way, the widening given in the two $\Delta\lambda$ columns, together with the remarks, showing in what respect the given character may be doubtful. Lines whose *n*-components are "fringed" are difficult to classify. Such "fringes" indicate very close, unresolved components, and these may be numerous. A field double that available here would probably show the full structure. Many lines were fully resolved by a field of 20,000 which had to be described as "fringed" for a field of 16,000. The degree of widening due to the fringes is given in the $\Delta\lambda$ column and a remark tells whether the fringes are toward the center or outwards. The number of components is estimated as closely as possible from the width of the fringes, but when the structure is very complex, an interrogation point is used without any attempt to give the number of components.

Although the doubtful elements which have been mentioned come into the estimates as to the character of lines, the large number of plates from which the material was taken gave an opportunity to study each line under various conditions of intensity and degree of separation, so that the classification as to character is probably as accurate as can be made without very much greater field-strength combined with as high resolving power as was here used.

4. WEIGHT.

Under this heading, each line for which measurement was possible is given the weight 3, 2, or 1, according as the quality of the Zeeman components for measurement is good, fair, or poor. This grading should be of much service in any use which is made of these tables. In attempts which the author has made to compare his measurements with those of others, the discordances were nearly always found to occur in the case of lines of such character that one or both sets of measurements were poor. If lines of high weight in each set are compared, a good check on the observations is obtained.

Lines of weight 3 have sharply defined components, and for such lines measurements of the same plate by different observers or different sets by the same observer usually give differences in the third decimal place only, while for many lines of this class the probable error is not greater than two or three thousandths of an Ångström. Only lines of weight 3 should be used in comparisons of field-strength.

Lines are weighted 2, when the line is reasonably strong, because the components are widened and probably compound, fringed, or perhaps single and poorly defined for some reason, so that the measurement is not so close as for lines weighted 3. Measurements of weight 2 have usually a probable error not greater than 10 per cent and may be used for quantitative comparisons where a high degree of precision is not required. When a component is measured from the no-field line, it is never weighted higher than 2. A line whose components are uniformly widened, each consisting of two or more components of about equal intensity, gives a better measurement than a line whose components are fringed, since in the latter case photographic conditions affect the distinctness of the maximum of each shaded component, this maximum being the part measured.

Weight 1 is given to lines which are very faint, much disturbed by blends, or of such complex structure that the components are extremely diffuse. The error of measurement for such lines may be large and the three decimal places are entered only for the sake of uniformity. However, the figures given show whether the line is to be classed as having small, medium, or large separation, and for this reason the inclusion of such lines is justified.

When measurements are given for both the *n*- and the *p*-components, the weight for each is given, separated by a comma. In case only the *p*-component is measured, a dash before the comma indicates the omission of the weight for the *n*-component.

5. VALUES OF $\Delta\lambda$.

The fifth and sixth columns of the tables contain the separation in Ångström units of the components given by light vibrating respectively perpendicular and parallel to the lines of magnetic force. (See foot-note, p. 19.) When there is an even number of components for the same polarization, measurements are made between the members of each pair which presents itself. A single value in one of these columns means that one pair of components is present. When there are two or more pairs, the largest separation is given first, but the innermost pair is designated "Pair I." When there is an odd number of components, any outer ones that may appear are measured from the central component, instead of being treated as pairs, and the values are listed beginning with the outermost on the violet side, the presence of a central component being indicated by 0.000. No attempt is made to give the relative intensity of the *n*- and *p*-components, as this depends largely upon the optical system. However, if there are more than two components for the same polarization, the relative intensity of the pairs (or of each component when there is an odd number) is given in parentheses after the value of the separation.

If either $\Delta\lambda$ column is blank for a certain line, this indicates that a single, sharp component appears for this polarization. Thus for all clear triplets, the *p*-component column is blank. If, however, the *p*-component is unresolved, but widened so as to indicate that a higher field would separate it into two or more, the letter "w" with subscript 1, 2, or 3 is used to show the degree of widening. Components marked "w_2" or "w_3" as a rule are certainly compound. A slight widening, which probably means more than one component, is indicated by "w_1," but this may in some cases result from the diffuse character of the no-field line.

There are many cases, especially in the *n*-component column, where a measurement is given, followed by "w" with a subscript. This means that a pair is measured, but each member of the pair is widened and probably compound. If the widening is uniform, there are probably two or more components of equal intensity. If the constituents of the widened component are of different intensity the component is shaded toward one side. Such a line has the degree of widening given and in addition is denoted in the "Remarks" column as "fringed" when each component shades off from the center, or as having "inner fringes" when the shading is toward the center.

The letters "n.m." indicate that a separation exists but is not measurable, usually by reason of the faintness of the components. In such cases it is possible, as a rule, to tell the character of the separation with fair certainty and the line is included on this account. Thus a faint but sharp *p*-component combined with traces of two sharp *n*-components is given as a triplet. The designation "n.m.w." is used when the components are hazy as well as faint.

6. VALUES OF $\Delta\lambda/\lambda^2$.

Since in most points relating to the theory of the Zeeman phenomenon, the values of $\Delta\lambda/\lambda^2$ rather than of $\Delta\lambda$ are considered (p. 4), the former quantity is entered in the seventh and eighth columns, the positions of the numbers in the column being the same as that of the corresponding values of $\Delta\lambda$. When λ is in Ångström units, the values given for $\Delta\lambda/\lambda^2$ are to be multiplied by 10^{-8}.

TABLE 1.—MEASUREMENTS OF ZEEMAN EFFECT FOR IRON.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	Δλ		$\Delta\lambda/\lambda^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
3659.663	1	Triple	2	0.176	.....	1.314	.....	
3669.666	2	Triple?	2	0.176	w_1	1.307	.....	
3670.240	1	Quadruple?	2	0.261w_1	w_2	1.938	.....	
3676.457	1	Triple	3	0.236	.....	1.746	.....	
3677.457	1	Triple	1	0.144	.....	1.065	.....	Faint in spark
3677.764	2	Triple	3	0.167	.....	1.234	.....	
3679.002	1	Triple	1	0.268	.....	1.980	.....	Faint in spark
3680.069	3	Sextuple?	3,3	0.296 w_2	0.111	2.186	0.820	
3682.382	3	Triple	2	0.230	.....	1.696	.....	
3683.229	2	Sextuple?	2	0.480 w_1	w_2	3.539	.....	*n*-comps. have inner fringes
3684.258	2	Triple?	3	0.170	w_1	1.252	.....	*p*-comps. almost resolved
3686.141	2	Sextuple?	2	0.194 w_2	w_2	1.428	.....	*n*- and *p*-comps. diffuse
3687.610	4	Triple	3	0.311	.....	2.286	.....	
3689.614	2	Sextuple?	2,1	0.373 w_1	0.097	2.739	0.712	
3690.870	1	Sextuple?	2,1	0.268 w_1	0.096	1.967	0.705	
3694.164	2	?	2	0.305 w_2	w_2	2.235	.....	*n*-comps. fringed. Probably 4 *p*-comps. blended
3695.194	2	Triple	3	0.261	.....	1.912	.....	
3697.567	1	Sextuple?	–,1	n.m. w_2	0.345	.....	2.522	*n*-comps. very diffuse. Probably more than 4
3701.234	2	?	2	0.236 w_2	w_2	1.723	.....	*n*-comps. fringed. Probably 4 *p*-comps. blended
3702.170	1	Triple	2	0.315	.....	2.298	.....	
3702.629	1	Triple?	2	0.333	w_1	2.428	.....	
3703.962	1	Triple	..	n.m.	.....	.....	.....	Faint
3704.603	2	Triple?	3	0.319	w_1	2.324	.....	
3705.708	4	8 or 10 comps.	2,3	0.294 w_2	0.147	2.141	1.070	Probably 3 pairs *n*-comps. May be 2 pairs *p*-comps.
3707.186	1	Quadruple	2,1	0.282	0.250	2.052	1.819	
3707.959	1	Quadruple	2,1	0.627	0.306	4.560	2.225	Blend with 3708.068
3708.068	4	Sextuple?	2	0.315 w_1	w_1	2.291	.....	*n*-comps. fringed
3709.389	4	Triple	3	0.312	.....	2.268	.....	
3711.364	1	Triple	3	0.216	.....	1.568	.....	
3716.054	1	Quadruple	1,1	0.290	0.146	2.100	1.057	
3716.591	2	Triple	3	0.394	.....	2.853	.....	
3718.554	1	Quintuple?	1,1	0.271 (1)	0.286	1.960	2.068	Unsymmetrical. Probably 3 *n*-, 2 *p*-comps. Red *n*-comp. not measurable. Red *p*-comp. half as strong as violet
				0.000 (2)	.....	0.000	.....	
				?	.....	?	.....	
3720.084	10	Triple?	2	0.268	.....	1.936	.....	All comps. may be compound. Line reverses readily and comps. are never sharp
3721.418	1	Triple	1	0.342	.....	2.470	.....	Faint in spark
3722.071	1	Triple	1	0.266	.....	1.920	.....	Faint in spark
3722.729	4	12 comps.	2,2	Pair IV, 0.415 (2)	Pair II, 0.195 (5)	2.994	1.407	
				Pair III, 0.311 (3)	Pair I, n.m. (1)	2.244	?	
				Pair II, 0.211 (3)	.....	1.522	.....	
				Pair I, 0.103 (2)	.....	0.743	.....	
3724.526	2	Triple	3	0.256	.....	1.845	.....	
3727.778	5	Septuple?	2	0.318 w_1	w_2	2.288	.....	*n*-comps have inner fringes. Probably 3 *p*-comps.
3730.534	1	Triple?	1	0.341 w_1	w_1	2.451	.....	Blend with faint lines
3731.093	1	Triple	1	0.176	.....	1.264	.....	
3732.545	2	Triple	3	0.399	.....	2.865	.....	
3733.469	3	Quintuple	3,3	0.157 (2)	0.322	1.127	2.311	
				0.000 (3)	.....	0.000	.....	
				0.158 (2)	.....	1.134	.....	
3735.014	10	Triple	2	0.310	.....	2.222	.....	
3735.485	1	Quadruple?	2,2	0.472 w_1	0.166	3.384	1.190	
3737.281	7	Septuple?	2	0.254 w_1	w_2	1.818	.....	*n*-comps. fringed. Probably 3 *p*-comps.
3738.454	2	Triple	3	0.207	.....	1.481	.....	
3743.508	6	Octuple	3,3	0.208 (4)	0.107 (2)	1.484	0.763	Comps. of faint line to red (computed 3743.615) are superposed on central and outer red *n*-comps. giving apparent dissymmetry. Compare 3788.046
				0.104 (2)	0.000 (3)	0.742	0.000	
				0.000 (2)	0.106 (2)	0.000	0.756	
				0.112 (2)	.....	0.799	.....	
				0.213 (5)	.....	1.520	.....	

TABLE 1.—MEASUREMENTS OF ZEEMAN EFFECT FOR IRON—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	Δλ		$\Delta\lambda/\lambda^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
3744.251	1	Septuple?	1,1	0.401 w_2	0.283 (1)	2.861	2.018	Probably 4 *n*-comps. Apparently 3 *p*-comps, but faint. Compare 3747
					0.000 (1)	.....	0.000	
					0.415 (1)	.....	2.960	
3745.717	5	Septuple?	2	0.228 w_1	w_2	1.624	.....	*n*-comps fringed. Probably 3 *p*-comps.
3746.058	4	Unaffected						
3747.065	1	Septuple?	1,1	0.413 w_2	0.306 (1)	2.941	2.180	Apparently same type as 3744. Comps. more distinct
					0.000 (2)	.....	0.000	
					0.341 (1)	.....	2.429	
3748.408	4	9 comps.?	2	Pair III, 0.316 (4)	w_3	2.250	.....	Probably 3 *p*-comps. almost resolved
				Pair II, 0.226 (3)	.....	1.609	.....	
				Pair I, 0.101 (1)	.....	0.719	.....	
3749.049	1	Quadruple?	2	0.240 w_1	w_2	1.708	.....	
3749.631	10	Triple	2	0.289	.....	2.055	.....	
3753.732	2	Triple	3	0.395	.....	2.803	.....	
3756.213	1	Triple?	2	0.300	w_1	2.126	.....	
3757.081	1	Triple?	1	0.197	w_1	1.396	.....	
3757.597	1	Triple	1	0.388	.....	2.747	.....	Faint in spark
3758.375	8	Triple	3	0.269	.....	1.905	.....	
3760.196	2	Triple	3	0.235	.....	1.662	.....	
3760.679	1	Quintuple?	2	0.146 (1)	w_2	1.032	.....	*n*-comp. appears as unsymmetrical triplet. No evidence of blend
				0.000 (1)	.....	0.000	.....	
				0.179 (1)	.....	1.265	.....	
3763.945	6	Triple	3	0.218	.....	1.538	.....	
3765.689	3	Triple	3	0.228	.....	1.608	.....	
3767.341	5	Unaffected						
3768.173	1	Triple	2	0.600	.....	4.225	.....	Faint in spark
3770.446	1	Triple	2	0.191	.....	1.343	.....	
3773.803	1	Unaffected						
3774.971	1	Sextuple	2,1	Pair II, 0.545 (1)	0.240	3.824	1.684	*p*-comps. faint
				Pair I, 0.274 (1)	.....	1.922	.....	
3776.600	1	Triple?	2	0.229	w_1	1.605	.....	
3777.593	1	Quadruple?	..	n.m.	n.m.	.....	.....	Very faint. Wide separation of *p*-comp.
3778.652	1	Triple	1	0.344	.....	2.408	.....	
3779.569	1	Triple?	1	0.277	.....	1.938	.....	
3781.330	1	?	..	n.m.	w_2	.....	.....	Many comps. *n* diffuse. Not resolved
3786.092	2	Triple	3	0.220	.....	1.535	.....	
3786.314	2	Triple?	..	n.m.w_2	w_2	.....	.....	*n*-comps. diffuse
3786.820	2	Unaffected						
3788.046	4	Octuple	3,3	0.214 (4)	0.111 (2)	1.491	0.774	Magnetic duplicate of 3743.508
				0.108 (2)	0.000 (3)	0.753	0.000	
				0.000 (1)	0.109 (2)	0.000	0.760	
				0.111 (2)	.....	0.774	.....	
				0.219 (4)	.....	1.526	.....	
3790.238	2	Sextuple?	2	0.164 w_2	w_2	1.142	.....	
3794.485	1	Triple	3	0.197	.....	1.369	.....	
3795.147	5	Septuple?	2	0.325	w_2	2.257	.....	*n*-comps. have inner fringes. Probably 3 *p*-comps.
3797.659	3	Triple	3	0.261	.....	1.809	.....	
3798.655	4	Triple	3	0.326	.....	2.259	.....	
3799.693	5	Triple	3	0.326	.....	2.258	.....	
3801.820	1	Quadruple?	1	0.190	w_2	1.314	.....	
3805.486	3	Triple	3	0.204	.....	1.409	.....	
3806.865	3	Triple	3	0.226	.....	1.559	.....	
3807.681	2	7 or 9 comps.	2,2	0.118 w_3	0.109 (1)	0.814	0.751	Sharp inner pair of *n*-comps. measured. Wide fringes probably indicate 2 outer pairs
					0.000 (2)	.....	0.000	
					0.100 (1)	.....	0.689	
3808.423	1	Quadruple?	1	0.227	w_2	1.565	.....	
3808.873	1	Triple	2	0.288	.....	1.737	.....	
3810.901	1	Triple	3	0.255	.....	1.756	.....	
3813.100	4	Septuple?	2	0.203 w_1	w_2	1.396	.....	*n*-comps. fringed. Probably 3 *p*-comps.
3813.781	1	Triple	1	0.266	w_1	1.828	.....	
3814.671	1	Quintuple	1,1	?		?		Faint. Blend makes *n*-comp. difficult
				0.000 (2)	0.324	0.000	2.226	
				0.182 (1)	.....	1.250	.....	

TABLE 1.—MEASUREMENTS OF ZEEMAN EFFECT FOR IRON—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	Δλ		$\Delta\lambda/\lambda^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
3815.987	10	Triple	2	0.264	.....	1.813	.....	
3816.490	1	Sextuple?	1	0.258 w_2	w_2	1.772	.....	
3817.786	1	Triple	1	0.169	.....	1.159	.....	Difficult
3820.586	10	Triple	2	0.282	.....	1.932	.....	Line reverses easily. Comps. never very sharp
3821.328	3	Triple	3	0.218	.....	1.493	.....	
3821.981	1	Triple	1	0.141	.....	0.965	.....	
3824.441	2	Triple	2	0.184	.....	1.258	.....	Not given by Rowland as *Fe*. Computed λ = 3824.463
3824.591	5	Triple	3	0.345	.....	2.359	.....	
3826.027	8	Septuple?	2	0.274 w_2	w_2	1.872	.....	*n*-comps. fringed. Probably 3 *p*-comps.
3827.980	7	Triple	2	0.225	.....	1.535	.....	
3830.896	1	Triple	n.m.	.....	.....	.....	.....	Faint
3831.002	1	Triple	1	0.222	.....	1.512	.....	
3833.458	1	Sextuple?	2	0.255 w_1	w_1	1.736	.....	
3834.364	6	Septuple?	2	0.248 w_1	w_2	1.687	.....	*n*-comps. fringed. Probably 3 *p*-comps.
3836.476	1	Triple	3	0.266	.....	1.808	.....	
3837.768	1	Quadruple?	2	0.198	w_2	1.344	.....	
3839.405	2	Triple	3	0.222	.....	1.506	.....	
3839.762	1	Triple?	1	0.257	w_1	1.748	.....	Enhanced line, diffuse
3840.580	4	9 comps.	2,1	Pair III, 0.337 (1)	0.061 (2)	2.285	0.414	Difficult. Comps. not fully resolved
				Pair II, 0.220 (2)	0.000 (3)	1.492	0.000	
				Pair I, 0.106 (4)	0.059 (2)	0.720	0.400	
3841.195	5	Triple	2	0.164	.....	1.112	.....	
3843.404	2	Triple	3	0.220	.....	1.490	.....	
3845.310	1	Sextuple?	2,2	0.234 w_3	0.197	1.582	1.332	*n*-comps. almost resolved
3846.554	1	Triple	2	0.247	.....	1.670	.....	Enhanced line
3846.943	2	Triple	3	0.300	.....	2.027	.....	
3850.118	4	Unaffected						
3850.962	2	Sextuple?	2,3	0.298 w_3	0.218	2.009	1.470	*n*-comps. almost resolved
3852.714	2	Quadruple?	2	0.268	w_1	1.805	.....	
3856.524	5	Triple	3	0.341	.....	2.293	.....	
3859.355	2	Triple	3	0.243	.....	1.632	.....	
3860.055	6	Triple	3	0.341	.....	2.289	.....	
3861.479	1	Triple	1	0.322	.....	2.160	.....	
3863.888	1	Triple	1	0.291	.....	1.949	.....	Very faint. Enhanced line
3865.674	4	Quintuple	3,3	0.172 (1)	0.340	1.151	2.275	
				0.000 (2)	.....	0.000	.....	
				0.171 (1)	.....	1.144	.....	
3867.356	2	Triple	3	0.339	.....	2.267	.....	
3869.692	1	Triple	2	0.406	.....	2.711	.....	
3871.963	1	Quadruple	2,2	0.272	0.125	1.814	0.834	Enhanced line
3872.639	4	12 comps.	2,3	Pair IV, 0.452 (1)	Pair II, 0.231 (6)	3.013	1.540	
				Pair III, 0.344 (2)	Pair I, n.m. (1)	2.293	.....	
				Pair II, 0.225 (2)	.....	1.500	.....	
				Pair I, 0.116 (1)	.....	0.773	.....	
3873.903	2	Triple	3	0.226	.....	1.506	.....	
3878.152	4	10 comps.?	2,3	0.311 w_3	0.151 w_1	2.067	1.004	Probably 6 *n*–, 4 *p*-comps.
3878.720	5	Triple	3	0.346	.....	2.300	.....	
3883.426	1	Triple	2	0.312	.....	2.069	.....	
3885.657	1	Sextuple?	2	0.234 w_1	w_1	1.550	.....	
3886.434	5	Triple	3	0.348	.....	2.304	.....	
3887.196	3	Sextuple?	2,2	0.335 w_2	0.117	2.217	0.774	
3888.671	4	11 comps.	2,2	0.190 (2)	Pair II, 0.235	1.256	1.554	Red *n*-comps. disturbed by blend
				0.128 (3)	Pair I, n.m.	0.846	.....	
				0.072 (3)	.....	0.476	.....	
				0.000 (1)	.....	0.000	.....	
				0.077 (3)	.....	0.509	.....	
				0.134 (3)	.....	0.886	.....	
				0.190 (2)	.....	1.256	.....	
3888.971	1	Triple	2	0.355	.....	2.347	.....	
3890.986	1	Triple	2	0.358	.....	2.364	.....	
3892.069	1	Quadruple?	2	0.237 w_1	w_2	1.564	.....	Red *n*-comp. stronger. Violet *p*-comp. stronger
3893.542	2	Quadruple?	3	0.269	w_1	1.775	.....	

TABLE 1.—MEASUREMENTS OF ZEEMAN EFFECT FOR IRON—Continued.

λ	Intensity.	Character of separation.	Weight.	Δλ		Δλ/λ²		Remarks.
				n-comp.	*p*-comp.	*n*-comp.	*p*-comp.	
3894.057	1	Triple	2	0.311	.....	2.051	.....	
3895.803	3	Triple	3	0.347	.....	2.286	.....	
3897.596	1	Triple	2	0.249	.....	1.638	.....	
3898.032	2	Triple	2	0.376	.....	2.474	.....	
3898.231	2	Quadruple	2,2	0.707	0.352	4.653	2.317	
3899.850	4	Triple	3	0.349	.....	2.294	.....	
3903.090	5	10 comps.?	2,2	0.278 w_2	0.152 w_1	1.825	0.998	Probably 6 *n*-, 4 *p*-comps.
3904.052	1	Sextuple?	2,1	0.233 w_1	0.098	1.529	0.643	
3906.169	1	Triple	..	n.m.	.....	.....	.....	Enhanced line
3906.628	3	Triple	3	0.347	.....	2.273	.....	
3908.077	1	Quadruple?	2	0.254	w_2	1.663	.....	
3909.976	1	Triple	1	0.350	.....	2.289	.....	Difficult blend with 3909.802
3913.775	1	Triple	2	0.326	.....	2.128	.....	
3916.879	2	Triple?	2	0.311	w_1	2.027	.....	
3917.324	2	Septuple?	2	0.554 w_2	w_2	3.610	.....	*n*-comps. have inner fringes. Probably 4 *n*-, 3 *p*-comps.
3918.464	1	Triple	..	n.m.				
3918.563	1	Triple	2	0.333	.....	2.169	.....	
3918.789	1	Triple	2	0.175	.....	1.139	.....	
3919.208	1	Quadruple?	1	0.251	w_2	1.634	.....	
3920.410	4	Triple	3	0.349	.....	2.271	.....	
3923.054	4	Triple	3	0.351	.....	2.281	.....	
3925.790	1	Quadruple?	2	0.300	w_2	1.946	.....	
3926.086	1	Triple	2	0.376	.....	2.439	.....	
3928.075	4	Triple	3	0.352	.....	2.281	.....	
3928.231	1	Triple	2	0.354	.....	2.282	.....	
3930.450	4	Triple	3	0.352	.....	2.279	.....	
3932.785	1	Quadruple?	1	0.413	w_2	2.670	.....	
3935.965	1	Sextuple?	2,2	0.319 w_1	0.227	2.059	1.465	Enhanced line
3937.479	1	Triple	2	0.384	.....	2.477	.....	
3939.288	1	Triple?	..	n.m. w_1	w_1	.....	.....	Enhanced line. Diffuse
3941.025	1	Triple?	2	0.460 w_1	w_1	2.962	.....	
3942.586	1	Triple	2	0.275	.....	1.770	.....	
3947.142	1	Quadruple?	1	0.243 w_1	w_2	1.560	.....	
3947.675	1	Quadruple?	1	0.383 w_1	w_1	2.457	.....	
3948.246	1	Triple	1	0.247	.....	1.585	.....	
3948.925	2	Triple	3	0.234	.....	1.500	.....	
3950.102	2	Triple	3	0.348	.....	2.230	.....	
3951.311	2	Triple?	2	0.288 w_1	w_1	1.844	.....	
3952.754	1	Sextuple?	2,1	0.287 w_1	0.145	1.837	0.927	Red *p*-comp. twice as strong as violet
3953.303	1	Triple	2	0.291	.....	1.862	.....	
3956.603	2	Triple	3	0.303	.....	1.935	.....	
3956.819	3	Triple	3	0.289	.....	1.846	.....	
3957.177	1	Triple	1	0.283 w_1	w_1	1.807	.....	Comps. hazy
3963.252	1	?	..	w_2	w_1	.....	.....	*n*-comps. not resolved
3964.663	1	Triple	1	0.420	.....	2.672	.....	Faint
3966.212	2	Septuple?	2	0.474 w_2	w_2	3.013	.....	Measurement is for wide pair *n*-comps. which have inner fringes. *p*-comps. not resolved, probably triple
3966.778	2	Sextuple?	2	0.338 w_2	w_2	2.147	.....	
3967.570	2	Triple	3	0.198	.....	1.258	.....	
3968.114	1	Triple?	..	n.m.	w_1	.....	.....	
3969.413	5	Septuple?	2	0.354 w_1	w_2	2.247	.....	Probably 4 *n*-, 3 *p*-comps.
3970.540	1	Triple	2	0.348	.....	2.207	.....	
3971.475	1	Sextuple?	2	0.212 w_1	w_1	1.344	.....	
3976.532	1	Triple?	1	0.330	w_1	2.088	}	Difficult blend
3976.692	1	Triple	1	0.319	.....	2.019		
3977.891	2	Triple	3	0.441	.....	2.787	.....	
3981.917	1	Sextuple?	2,2	0.240 w_2	0.127	1.513	0.800	
3984.113	2	Triple	3	0.216	.....	1.361	.....	
3985.539	1	Triple	2	0.282	.....	1.775	.....	
3986.321	1	Sextuple?	2	0.196 w_2	w_2	1.234	.....	
3990.011	1	Triple?	1	0.293 w_1	w_1	1.840	.....	
3990.525	1	Triple?	2	0.251	w_1	1.577	.....	
3994.265	1	Triple	2	0.283	.....	1.774	.....	

TABLE 1.—MEASUREMENTS OF ZEEMAN EFFECT FOR IRON—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	$\Delta\lambda$		$\Delta\lambda/\lambda^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
3996.140	1	?	..	w_3	w_2	.....	.....	*n*-comp. not resolved
3997.115	1	Triple	1	0.259	.....	1.621	.....	Faint
3997.547	3	Triple	3	0.266	.....	1.664	.....	
3998.205	2	Sextuple?	2	0.226 w_1	w_1	1.414	.....	
4001.814	1	Triple	3	0.415	.....	2.591	.....	
4005.408	6	13 comps.?	2	0.461 w_3	w_3	2.874	.....	Measurement is for outer pair *n*-comps. Wide inner fringes, probably at least 8 *n*-comps. and 5 *p*-comps. Compare 4132.235
4006.464	1	Triple?	1	0.211	w_1	1.315	.....	Blend
4006.776	1	Triple	1	0.383	.....	2.385		
4007.429	1	Triple	2	0.176	.....	1.096	.....	
4009.864	2	Septuple	2,2	Pair II, 0.470 (1)	0.085 (1)	2.923	0.529	
				Pair I, 0.284 (3)	0.000 (2)	1.766	0.000	
					0.089 (1)	.....	0.553	
4013.964	1	Triple?	1	0.236 w_1	w_1	1.465	.....	
4014.677	2	Triple	3	0.250	.....	1.551	.....	
4017.308	1	Sextuple?	2	0.397 w_1	w_2	2.460	.....	
4018.420	1	Triple	1	0.288	.....	1.784	.....	Very faint
4022.018	2	Sextuple?	2	0.272 w_1	w_1	1.681	.....	
4024.881	1	Triple?	1	0.209 w_1	w_1	1.290	.....	*n*-comps. scarcely resolved
4029.796	1	Quadruple?	2	0.311	w_1	1.915	.....	
4030.646	1	Sextuple?	2	0.274 w_1	w_1	1.685	.....	
4032.117	1	Triple	2	0.211	.....	1.298	.....	
4040.792	1	Triple	2	0.254	.....	1.555	.....	
4044.056	1	?	..	n.m. w_2	w_3	.....	.....	Comps. diffuse
4044.766	1	Triple?	2	0.319	w_1	1.950	.....	
4045.975	15	Triple	3	0.298	.....	1.820	.....	
4062.599	2	Sextuple?	2,2	0.418 w_2	0.097	2.532	0.588	
4063.759	10	Triple	3	0.269	.....	1.628	.....	
4067.139	1	Sextuple?	2,2	0.402 w_2	0.189	2.430	1.143	
4068.137	1	Quadruple?	2	0.418	w_2	2.525	.....	
4070.930	1	Triple?	2	0.366	w_1	2.208	.....	
4071.908	8	Triple	2	0.170	.....	1.025	.....	
4073.921	1	Triple	2	0.360	.....	2.169	.....	
4074.947	1	Octuple?	2,2	0.302 w_3	0.149	1.819	0.897	Probably 6 *n*-comps.
4076.792	2	Triple	2	0.386	.....	2.322	.....	
4078.515	1	Triple	2	0.184	.....	1.106	.....	
4079.996	1	Triple	2	0.479	.....	2.877	.....	
4080.368	1	Triple?	..	n.m.	w_1	.....	.....	Very faint
4084.647	1	Triple?	2	0.300	w_1	1.798	.....	Blend makes measurement difficult
4085.161	1	Triple?	1	0.311	w_2	1.864		
4085.467	1	Triple?	1	0.400	w_2	2.397		
4096.129	1	Triple?	2	0.237	w_1	1.413	.....	
4098.335	1	Sextuple?	2	0.383 w_1	w_2	2.281	.....	
4100.901	1	Triple	1	0.302	.....	1.796	.....	Faint
4107.649	2	Triple	3	0.397	.....	2.352	.....	
4109.953	2	Sextuple	2,3	Pair II, 0.382 (1)	0.191	2.261	1.131	
				Pair I, 0.188 (1)	.....	1.113	.....	
4114.606	1	Sextuple?	2,2	0.376 w_1	0.135	2.220	0.797	
4118.708	3	Triple	3	0.271	.....	1.597	.....	
4120.368	1	Triple	2	0.244	.....	1.437	.....	
4121.963	1	Triple?	..	n.m.	w_2			
4122.673	1	Quadruple?	..	n.m.	w_2	.....	.....	*n*-comps. hardly separated. *p*-comps. almost resolved
4123.907	1	Triple?	1	0.402 w_1	w_2	2.364	.....	Comps. faint and diffuse
4126.040	1	Triple?	1	0.370	w_2	2.173	.....	Blend makes measurement difficult
4126.344	1	Triple?	1	0.335	w_1	1.968		
4126.798	1	Triple	1	0.284	.....	1.667		
4127.767	1	Triple	3	0.196	.....	1.150	.....	
4130.196	1	Triple	..	n.m.	w_1	.....	.....	Faint, *n*-comps. rather widely separated
4132.235	4	13 comps.?	2	0.510 w_3	w_3	2.987	.....	Measurement is for outer *n*-comps. Wide inner fringes, indicating 4 pairs. 5 *p*-comps. almost resolved. Similar to 4005.408

TABLE 1.—MEASUREMENTS OF ZEEMAN EFFECT FOR IRON—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	$\Delta\lambda$		$\Delta\lambda/\lambda^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
4133.062	2	Sextuple?	2	0.273 w_1	w_1	1.598	.....	
4134.840	2	Sextuple?	2	0.303 w_1	w_1	1.772	.....	
4136.678	1	Triple?	2	0.252	w_1	1.472	.....	
4137.156	1	Triple	2	0.314	.....	1.834	.....	
4140.089	1	Triple	..	n.m.	.....	.....	.....	Very faint
4142.025	1	Triple?	2	0.392 w_1	w_2	2.285	.....	
4143.572	3	Quadruple?	2	0.280	w_1	1.630	.....	
4144.038	5	Septuple?	2	0.393 w_1	w_2	2.288	.....	*n*-comps. have inner fringes. Probably 3 *p*-comps.
4147 836	1	Sextuple?	2	0.340 w_2	w_2	1.976	.....	Diffuse *p*-comp. appears stronger on violet side. Possibly blend
4149.533	1	Triple?	2	0.397 w_1	w_1	2.305	.....	
4154.071	2	Triple	1	0.379	.....	2.196	.....	
4154.667	2	Triple	2	0.379	.....	2.195	.....	
4154.976	2	Triple	1	0.385	.....	2.230	.....	
4156.970	2	Sextuple?	2,2	0.367 w_1	0.121	2.123	0.700	
4157.948	1	Sextuple?	2	0.415 w_2	w_2	2.400	.....	
4158.959	1	?	1	0.589 w_1	w_3	3.405	.....	*p*-comp. very diffuse
4171.068	1	Sextuple?	2,2	0.390 w_2	0.117	2.242	0.672	
4172.296	1	Triple	2	0.315	.....	1.810	.....	
4172.923	1	Triple	..	n.m.				
4173.480	1	Quadruple	1,1	0.470	0.185	2.698	1.062	Blend with next line makes measurement difficult
4173.624	1	Triple	..	n.m.	.....	.....	.....	Enhanced line
4175.082	1	Triple?	2	0.374	w_1	2.146	.....	
4175.806	2	Triple	2	0.296	.....	1.697	.....	
4176.739	1	Triple	1	0.420	.....	.....	2.407	
4179.025	1	?	..	w_3	w_2	.....	.....	Comps. very diffuse, not resolved. Enhanced line
4181.919	4	Triple	3	0.339	.....	1.938	.....	
4182.548	1	Quadruple?	1	0.272 w_1	w_2	1.555	.....	Faint
4185.058	2	Triple	3	0.390	.....	2.227	.....	
4187.204	4	Septuple?	2	0.395 w_1	w_2	2.253	.....	*n*-comps. fringed. Probably 3 *p*-comps.
4187.943	4	Triple	3	0.402	.....	2.292	.....	
4191.595	3	Septuple	2,2	Pair II, 0.540 (1)	0.135 (1)	3.073	0.768	
				Pair I, 0.264 (4)	0.000 (2)	1.502	0.000	
					0.143 (1)	.....	0.813	
4195.492	1	Triple	2	0.320	.....	1.818	.....	
4196.372	1	Triple	1	0.359	.....	2.039	.....	Faint
4198.494	3	Triple	3	0.383	.....	2.172	.....	
4199.267	5	Triple	3	0.276	.....	1.565	.....	
4200.148	1	Sextuple?	1	0.364 w_3	w_3	2.062	.....	Faint and diffuse
4201.089	1	Triple	1	0.438	.....	2.482	.....	Faint
4202.198	6	10 comps.?	2,2	0.323 w_3	0.147 w_1	1.829	0.832	Probably 6 *n*-, 4 *p*-comps.
4204.101	1	Triple	3	0.373	.....	2.110	.....	
4206.862	1	Triple	1	0.338	.....	1.910	.....	Faint
4207.291	1	Triple	1	0.317	.....	1.791	.....	Faint
4208.766	1	Quadruple?	1	0.413	w_2	2.332	.....	Faint
4210.494	3	Triple	3	0.806	.....	4.547	.....	
4210.561	1	Triple	1	0.411	.....	2.319	.....	Enhanced line *Fe?* Not identified by Rowland
4213.812	1	Triple	2	0.392	.....	2.207	.....	
4216.351	1	Sextuple?	2,2	0.457 w_2	0.236	2.571	1.328	
4217.720	1	Sextuple?	1	0.402 w_2	w_3	2.259	.....	Comps. very diffuse
4219.516	3	Triple	3	0.284	.....	1.594	.....	
4220.509	1	Triple	2	0.368	.....	2.066	.....	
4222.382	2	Triple	3	0.475	.....	2.665	.....	
4224.337	1	Sextuple?	1	0.439 w_1	w_1	2.460	.....	
4225.619	1	Sextuple?	2	0.448 w_1	w_2	2.508	.....	
4226.116	1	Triple	..	n.m.	.....	.....	.....	Blend with adjacent lines
4226.584	1	Triple?	1	0.381	w_2	2.133	.....	
4227.606	4	Triple	2	0.309	.....	1.728	.....	
4233.328	2	Sextuple?	2	0.282 w_1	w_3	1.574	.....	Enhanced line
4233.772	2	9 comps.	2,2	Pair III, 0.780 (1)	0.140 (2)	4.351	0.780	
				Pair II, 0.550 (2)	0.000 (3)	3.068	0.000	
				Pair I, 0.265 (5)	0.140 (2)	1.478	0.780	

TABLE 1.—MEASUREMENTS OF ZEEMAN EFFECT FOR IRON—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	Δλ		Δλ/λ²		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
4236.112	4	Triple	3	0.452	.....	2.519	.....	
4238.970	1	Triple	2	0.320	.....	1.781	.....	
4240.014	1	Triple	2	0.440	.....	2.447	.....	
4245.422	1	Triple	3	0.493	.....	2.736	.....	
4246.251	1	Triple	1	0.273	.....	1.514	.....	
4247.591	1	Triple	3	0.356	.....	1.973	.....	
4248.384	1	Triple	2	0.377	.....	2.089	.....	
4250.287	8	Septuple?	2	0.382 w_1	w_3	2.115	.....	*n*-comps. fringed. Probably 3 *p*-comps
4250.945	9	12 comps.?	2,2	0.246 w_3	0.211 w_1	1.361	1.168	Probably 8 *n*-, 4 *p*-comps.
4260.640	10	Triple	3	0.423	.....	2.330	.....	
4267.122	1	Triple	1	0.300	.....	1.648	.....	
4267.985	1	Triple	1	0.528	.....	2.899	.....	
4268.915	1	Triple?	1	0.462	w_1	2.535	.....	
4271.325	9	Triple	3	0.394	.....	2.160	.....	
4271.934	10	Triple	3	0.341	.....	1.868	.....	
4282.565	1	Septuple?	2	0.310 w_2	w_3	1.691	.....	*n*-comps. fringed. Probably 3 *p*-comps.
4285.605	1	Triple	3	0.315	.....	1.715	.....	
4294.301	5	Sextuple?	2,2	0.319 w_2	0.138	1.730	0.748	*n*-comps. almost resolved
4298.195	1	Triple?	2	0.457	w_1	2.474	.....	
4299.410	5	Triple	3	0.406	.....	2.197	.....	
4302.353	1	Triple	2	0.316	.....	1.707	.....	Enhanced line
4303.337	1	Sextuple?	2,2	0.415 w_2	0.265	2.241	1.431	Enhanced line
4305.614	1	Quadruple?	1	0.328 w_1	w_2	1.769	.....	
4308.081	15	Triple	3	0.320	.....	1.724	.....	
4309.541	1	Triple	2	0.325	.....	1.750	.....	
4315.262	3	Sextuple?	3,3	0.517 w_1	0.090	2.777	0.483	
4325.939	15	Triple	3	0.245	.....	1.309	....	
4327.274	1	Triple	2	0.313	.....	1.672	.....	
4328.080	1	Triple	2	0.246	.....	1.313	.....	
4337.216	2	Sextuple?	2,3	0.264 w_2	0.154	1.404	0.819	
4346.725	1	Triple?	1	0.292	w_2?	1.545	.....	Blend with air lines
4351.930	1	Septuple?	1	0.311 w_2	w_2	1.642	.....	Probably 3 *p*-comps. May be *Cr*, but given by Lockyer as enhanced line *Fe*
4352.908	2	Septuple?	2,3	0.416 w_3	0.075 (1) 0.000 (2) 0.075 (1)	2.195	0.396 0.000 0.396	*n*-comps. fringed
4367.749	1	Triple	2	0.311	.....	1.630	.....	
4369.941	2	Triple	3	0.282	.....	1.477	.....	
4376.107	2	Triple	3	0.424	.....	2.214	.....	
4383.720	20	Triple	3	0.332	.....	1.727	.....	
4385.548	1	Quadruple	2,2	0.367	0.391	1.910	2.032	Enhanced line
4388.057	1	Triple	..	n.m.	.....	.....	.....	*n*-comps. blended with adjacent lines
4388.571	1	Triple	2	0.432	.....	2.243	.....	
4391.123	1	Triple	..	n.m.	.....	.....	.....	Faint
4404.927	15	Triple	3	0.334	.....	1.720	.....	
4407.871	1	Triple?	2	0.631	w_1	3.247	.....	
4408.582	1	Triple?	2	0.488	w_1	2.511	.....	
4415.293	10	Septuple?	2	0.338 w_2	w_2	1.734	.....	*n*-comps. have inner fringes. Probably 3 *p*-comps.
4422.741	1	Sextuple	2,3	Pair II, 0.432 (1) Pair I, 0.154 (1)	0.280	2.208 0.787	1.431	
4427.482	2	Triple	3	0.430	.....	2.194	.....	
4430.785	1	Triple	2	0.719	.....	3.662	.....	
4433.390	1	Triple?	..	n.m. w_2	w_2	.....	.....	Comps. diffuse and blended with air band
4442.510	2	10 comps.?	2,2	0.485 w_3	0.184 w_1	2.458	0.932	Probably 6 *n*-, 4 *p*-comps.
4443.365	2	Triple	2	0.170	.....	0.861	.....	
4447.892	2	Sextuple	2,3	Pair II, 0.721 (1) Pair I, 0.449 (1)	0.307	3.644 2.269	1.552	Close to air line
4454.552	1	Sextuple?	2,2	0.445 w_1	0.173	2.243	0.872	
4459.301	2	Sextuple?	2,2	0.449 w_2	0.127	2.258	0.639	
4461.818	1	Triple	3	0.435	.....	2.185	.....	
4466.727	2	Sextuple?	2	0.343 w_1	w_1	1.719	.....	

TABLE 1.—MEASUREMENTS OF ZEEMAN EFFECT FOR IRON—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	$\Delta\lambda$		$\Delta\lambda/\lambda^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
4469.545	1	Triple?	2	0.438 w_1	w_1	2.192	.....	
4476.185	2	Septuple?	2	0.306 w_1	w_2	1.527	.....	*n*-comps. fringed. Probably 3 *p*-comps.
4482.338	1	Sextuple?	1,1	0.401 w_1	0.146	1.996	0.727	*n*-comps. very diffuse
4482.438	2	Quadruple?	1,1	0.139	0.229	0.692	1.140	Probably also outer pair *n*-comps. Close blend with preceding
4484.392	1	Sextuple?	2	0.385 w_1	w_1	1.915	.....	
4489.351	1	Triple	..	n.m.	.....	.....	.....	Enhanced line
4491.570	1	Triple?	..	w_2	.....	.....	.....	*n*-comps. close, not resolved. Enhanced line
4494.738	2	Septuple?	2	0.302 w_2	w_3	1.495	.....	*n*-comps. fringed. Probably 3 *p*-comps.
4508.455	1	Triple	1	0.184	.....	0.905	.....	Enhanced line. Comps. diffuse
4515.508	1	Triple	2	0.332	.....	1.628	.....	Enhanced line
4520.397	1	Triple	2	0.472	.....	2.310	.....	Enhanced line
4522.802	1	Triple	2	0.274	.....	1.339	.....	Enhanced line
4525.314	1	Sextuple?	1,2	0.457 w_2	0.164	2.232	0.801	
4528.798	3	Septuple?	2	0.358 w_2	w_3	1.745	.....	*n*-comps. fringed. Probably 3 *p*-comps.
4531.327	1	Sextuple?	2,2	0.398 w_1	0.104	1.939	0.506	
4548.024	1	Triple	2	0.311	.....	1.504	.....	
4549.642	1	Triple	2	0.319	.....	1.541	.....	Enhanced line
4556.063	1	Triple	1	0.311	.....	1.498	.....	Blend with 4556.306. Enhanced line
4556.306	1	Triple?	..	n.m.	w_1	.....	.....	
4584.018	2	Triple	2	0.376	.....	1.789	.....	Enhanced line
4592.840	1	Sextuple?	2,2	0.416 w_1	0.126	1.972	0.597	
4603.126	1	Sextuple?	2	0.566 w_1	w_2	2.671	.....	
4611.469	1	Triple	2	0.652	.....	3.067	.....	
4619.468	1	Quadruple?	2	0.581 w_1	w_2	2.723	.....	
4629.521	1	Triple	2	0.398	.....	1.857	.....	Very close to air line. Enhanced line
4637.685	1	Triple?	..	n.m.	w_1	.....	.....	*n*-comps. diffuse. Close to air line
4638.193	1	Triple	..	n.m.	.....	.....	.....	
4647.617	1	Triple	2	0.392	.....	1.814	.....	
4654.800	1	Triple?	1	0.543 w_1	w_1	2.506	.....	*n*- and *p*-comps. diffuse
4667.626	1	Triple	2	0.481	.....	2.207	.....	
4668.331	1	Sextuple?	1	0.362 w_2	w_1	1.661	.....	
4679.027	1	Triple	2	0.465 w_1	.....	2.124	.....	
4691.602	1	Triple	2	0.358	.....	1.626	.....	
4707.457	1	Triple?	2	0.365	w_1	1.647	.....	
4710.471	1	Triple	1	0.242	.....	1.091	.....	Blend with air line
4736.031	1	Triple?	1	0.405 w_1	.....	1.805	.....	Weak, rather diffuse
4736.963	1	Sextuple?	2	0.426 w_2	w_1	1.898	.....	
4741.718	1	Triple	..	n.m.	.....	.....	.....	Faint
4745.992	1	Triple?	..	n.m. w_2	w_1	.....	.....	Comps. weak and diffuse
4787.003	1	Triple	2	0.409	.....	1.785	.....	
4788.952	1	Triple?	..	n.m.	.....	.....	.....	*n*-comps. diffuse
4789.849	1	Sextuple?	2	0.352 w_1	w_2	1.534	.....	
4839.734	1	Triple	..	n.m.	.....	.....	.....	Too weak to measure
4859.928	2	Octuple	2,2	n.m.	.....	.....	.....	Strong central *n*-comp. Trace of faint outer pair
				0.275 (1)	0.271 (2)	1.166	1.147	
				0.000 (4)	0.000 (3)	0.000	0.000	
				0.289 (1)	0.269 (2)	1.222	1.139	
				n.m.	.....	.....	.....	
4871.512	3	11 comps.?	1,2	0.336 w_2	0.193 (1)	1.414	0.813	*n*-comps. fringed. Probably 3 pairs
					0.093 (2)	.....	0.392	
					0.000 (3)	.....	0.000	
					0.087 (2)	.....	0.366	
					0.181 (1)	.....	0.762	
4872.332	2	Sextuple	2,3	Pair II, 1.044 (3)	0.538	4.400	2.264	
				Pair I, 0.515 (2)	.....	2.171	.....	
4878.407	1	Triple	3	1.092	.....	4.574	.....	Violet comp. 3/2 stronger than red
4890.948	3	10 comps.?	2,2	0.635 w_3	0.341	2.656	1.424	*n*-comps. uniformly widened, probably 3 pairs. Trace of inner pair *p*-comps.

TABLE 1.—MEASUREMENTS OF ZEEMAN EFFECT FOR IRON—Continued.

λ	Intensity.	Character of separation.	Weight.	Δλ		$\Delta\lambda/\lambda^2$		Remarks.
				n-comp.	*p*-comp.	*n*-comp.	*p*-comp.	
4891.683	5	?	2	0.388 w_2	w_2	1.620	.....	*n*-comps. fringed. Probably 3 *p*-comps.
4903.502	1	Sextuple?	2,1	0.866 w_1	0.152	3.600	0.632	
4911.963	1	Triple	2	0.397	.....	1.644	.....	
4919.174	5	Sextuple?	2,2	0.591 w_2	0.270	2.441	1.115	
4920.685	8	Triple?	2	0.447 w_2	w_2	1.845	.....	Probably complex, but widening may be due to strength
4924.107	10	Septuple?	2	0.615 w_2	w_2	2.537	.....	*n*-comps. fringed. At least 3 *p*-comps. Enhanced line
4924.956	1	Quadruple?	..	n.m.	n.m.	.....	.....	Comps. weak and diffuse
4938.997	1	Quadruple?	2	0.737 w_1	w_2	3.023	.....	
4939.868	1	Triple	2	0.580	.....	2.378	.....	
4946.568	1	Triple	2	0.481	.....	1.968	.....	
4957.480	2	Sextuple?	2,2	0.630 w_1	0.190	2.565	0.773	
4957.785	5	Triple?	2	0.501 w_1	w_2	2.307	.....	Widening may be due to strength
4966.270	1	Triple	2	0.588	.....	2.134	.....	
4973.281	1	Quadruple?	1	0.248 w_1	w_1	1.003	.....	
4978.785	1	Unaffected?	..	.....	w_2	.....	.....	Only narrow *n*-comp. visible. Faintness of line may prevent appearance of others. Possibly similar to 4859.928
4982.682	1	Triple?	2	0.469	w_1	1.890	.....	
4983.433	1	Triple	1	0.587	.....	2.362	.....	Blend with adjacent lines
4984.028	1	Quadruple?	2	0.549	w_2	2.209	.....	
4985.432	1	Triple	2	0.452	.....	2.337	.....	
4985.730	1	Sextuple?	2	0.717 w_1	w_2	2.885	.....	
4991.452	1	Triple?	2	0.504 w_1	w_1	2.023	.....	Faint
4994.316	1	Triple	2	0.581	.....	2.332	.....	
5002.044	1	Triple	2	0.415	.....	1.660	.....	Close to air line
5005.896	2	Triple	1	0.490	.....	1.953	.....	*n*-comps. blend with adjacent line
5006.306	1	Sextuple?	2	0.295 w_1	0.182	1.176	0.724	
5012.252	1	Triple	3	0.537	.....	2.136	.....	
5015.123	1	Quadruple?	2	0.374	w_2	1.488	.....	
5018.629	3	Quadruple?	3	0.742	w_2	2.944	.....	Enhanced line
5022.414	1	Triple	2	0.263	.....	1.043	.....	
5027.305	1	Triple?	1	0.505	w_2 ?	1.998	.....	Diffuse comps. due to blend with 5027.939
5028.308	1	Triple	2	0.353	.....	1.396	.....	
5039.428	1	Triple	2	0.600	.....	2.363	.....	
5041.255	1	Triple	2	0.498	w_2 ?	1.959	.....	Widening of *p*-comp. probably due to blend with 5041.069
5041.936	1	Triple?	2	0.517	w_1	2.034	.....	
5050.008	1	Triple?	3	0.439	w_1	1.723	.....	
5051.825	1	Triple	3	0.521	.....	2.042	.....	
5065.207	1	Triple?	1	0.341 w_2	w_2	1.329	.....	Comps. diffuse, disturbed by blend
5068.944	1	Triple	3	0.684	.....	2.664	.....	
5074.932	1	Sextuple?	2	0.408 w_1	w_2	1.585	.....	
5079.409	1	?	1	0.457 w_2	w_2	1.771	.....	Blend with adjacent lines. Probably at least 7-comps.
5079.921	1	Septuple?	1,1	0.737	0.206 (1)	2.856	0.798	Faint. Probably weak inner pair *n*-comps.
					0.000 (2)	.....	0.000	
					0.210 (1)	.....	0.814	
5083.518	1	Triple	2	0.475	.....	1.840	.....	
5090.954	1	Sextuple?	..	n.m. w_2	w_2	.....	.....	Comps. weak and diffuse
5097.175	1	Sextuple?	2	0.513 w_1	w_2	1.974	.....	
5098.885	1	Quadruple?	2	0.607	w_2	2.333	.....	
5107.619	1	Triple	1	0.404	.....	1.549	.....	Blend
5107.823	1	Sextuple?	1	0.625 w_1	w_2	2.394		
5110.574	1	Quadruple	1,1	0.539	0.226	2.066	0.866	Measurement difficult owing to blend with 5109.827
5123.899	1	Unaffected						
5125.300	1	Sextuple?	2	0.519 w_1	w_2	1.976	.....	
5127.533	1	Triple	2	0.676	.....	2.572	.....	
5131.642	1	Triple	2	0.957	.....	3.634	.....	Very faint
5133.870	1	Sextuple?	2	0.459 w_1	w_2	1.743	.....	*p*-comp. almost resolved

Table 1.—Measurements of Zeeman Effect for Iron—Continued.

λ	Intensity.	Character of separation.	Weight.	Δλ		Δλ/λ²		Remarks.
				n-comp.	*p*-comp.	*n*-comp.	*p*-comp.	
5137.558	1	Sextuple?	2	0.567 w_1	w_2	2.148	.....	
5139.427	1	Triple?	2	0.716	w_1	2.713 }	.....	Close blend makes judgment of *p*-comps. difficult
5139.644	1	Quadruple?	2	0.693	w_2	2.622 }	.....	
5143.111	1	Triple?	1	0.578	w_1	2.184	.....	Blend with adjacent lines
5151.020	1	Quadruple?	1	0.629 w_1	w_3	2.371	.....	Very faint
5152.087	1	Octuple?	..	n.m.	n.m.	.....	.....	Probably 5 *n*-, 3 *p*-comps. Very faint
5159.231	1	Triple?	1	0.442 w_2	w_3	1.662	.....	Comps. very diffuse
5162.449	1	Triple?	2	0.586	w_3	2.200	.....	
5167.678	8	Triple	2	0.462	.....	1.730	.....	
5169.220	10	7 or 9 comps.?	2	0.563 w_2	w_3	2.106	.....	Enhanced line. *n*-comps. fringed and probably compound. *p*-comp. much widened with strong center. Blend with 5169.069.
5171.778	1	Triple	3	0.521	.....	1.949	.....	
5191.629	1	Septuple?	2	0.702 w_2	w_3	2.606	.....	*n*-comps. fringed. Probably 3 *p*-comps.
5192.523	1	Sextuple?	2,2	0.749 w_1	0.213	2.780	0.790	
5195.113	1	Triple	3	0.457	.....	1.695	.....	
5195.647	1	Quadruple?	..	n.m.	w_2	.....	.....	Comps. very diffuse
5197.743	1	Triple	2	0.304	.....	1.125	.....	Enhanced line
5198.888	1	Quadruple?	..	n.m.	w_3	.....	.....	Comps. very diffuse
5202.516	1	Triple	3	0.683	.....	2.525	.....	
5208.776	1	Triple?	2	0.623	w_1	2.294	.....	
5215.353	1	Triple?	2	0.625	w_1	2.296	.....	
5216.437	1	Triple	2	0.305	.....	1.120	.....	
5217.552	1	Triple?	2	0.615	w_1	2.259	.....	
5225.695	1	Quadruple?	..	n.m.	n.m.	.....	.....	Very faint, *p*-comp. apparently wide doublet
5227.043	1	Sextuple?	2,2	0.949 w_2	0.281	3.472	1.030	Probably 4 *n*-comps.
5227.362	5	Triple	3	0.413	.....	1.512	.....	
5230.030	1	Triple?	2	0.615	w_1	2.248	.....	
5233.122	5	Septuple?	2	0.507 w_2	w_3	1.851	.....	*n*-comps. fringed. Probably 3 *p*-comps.
5234.791	1	Triple	2	0.385	.....	2.147	.....	Enhanced line
5242.658	1	Triple	2	0.385	.....	1.400	.....	
5250.817	1	Triple?	2	0.618	w_1	2.243	.....	
5263.486	1	Triple	2	0.651	.....	2.352	.....	
5266.738	3	7 or 9 comps?	2	0.502 w_3	w_3	1.810	.....	*n*-comps. widely fringed. Probably 3 *p*-comps.
5269.723	8	Triple?	3	0.501	w_1	1.804	.....	
5270.558	5	Triple	3	0.299	.....	1.076	.....	
5273.339	1	Triple	2	0.651	.....	2.343	.....	
5276.169	1	Sextuple?	1	0.431 w_2	w_2	1.547	.....	Enhanced line
5281.971	2	?	1	0.311 w_3	w_3	1.115	.....	*n*-comps. strongly fringed. Probably 5 *p*-comps.
5283.802	3	Triple	3	0.623	.....	2.232	.....	
5302.480	2	Triple	3	0.632	.....	2.272	.....	
5316.790	4	Triple?	2	0.455 w_1	w_2	1.610	.....	Enhanced line. Diffuse comps. may be due to character of line
5324.373	5	Triple	3	0.648	.....	2.286	.....	Red comp. slightly stronger than violet
5328.236	7	Septuple?	2	0.470 w_1	w_3	1.656	.....	*n*-comps. fringed. Probably 3 *p*-comps.
5328.696	3	Sextuple?	2,2	0.488 w_2	0.275	1.718	0.968	
5340.121	2	Triple	2	0.664	.....	2.329	.....	
5341.213	3	?	1,2	0.486 w_3	0.429	1.703	1.502	*n*-comps. blurred, probably at least 6
5353.571	1	Triple	..	n.m.	.....	.....	.....	Very faint
5365.069	1	Sextuple?	1	0.354 w_2	w_3	1.229	.....	Comps. very diffuse
5365.596	1	Triple	1	0.471	.....	1.636	.....	Blend with preceding line
5367.669	1	Triple?	2	0.414	w_1	1.437	.....	Diffuse
5370.166	2	Triple?	2	0.456	w_1	1.581	.....	Diffuse
5371.734	6	9 comps.?	2	0.413 w_2	w_2	1.431	.....	*n*-comps. fringed. Probably 6 *n*-, 3 *p*-comps.

TABLE 1.—MEASUREMENTS OF ZEEMAN EFFECT FOR IRON—Continued.

λ	Intensity.	Character of separation.	Weight.	Δλ		Δλ/λ²		Remarks.
				n-comp.	*p*-comp.	*n*-comp.	*p*-comp.	
5383.578	4	Triple?	3	0.480 w_1	w_1	1.656	.....	
5393.375	3	Triple	2	0.673	.....	2.314	....	
5397.344	6	Sextuple?	2.3	0.630 w_2	0.222	2.163	0.762	
5404.357	5	Triple?	2	0.467 w_1	w_1	1.599	.....	Diffuse
5405 989	6	9 comps.?	2,2	Pair II, 0.461 (1)	0.117 (2)	1.577	0.400	Probably third pair *n*-comps. outside
				Pair I, 0.222 (4)	0.000 (3)	0.760	0.000	
					0.121 (2)	.....	0.414	
5411.124	3	Triple?	2	0.435 w_1	w_1	1.486	.....	Diffuse
5415.416	5	Triple?	2	0.510 w_1	w_1	1.739	.....	Diffuse
5424.290	5	Triple?	2	0.498 w_1	w_1	1.693	.....	Diffuse
5429.911	6	10 comps.?	2,3	0.607 w_2	0.300	2.059	1.017	3 or possibly 4 pairs *n*-comps. Probably weak inner pair *p*-comps.
5434.740	5	Unaffected						
5445.259	2	Triple?	2	0.415	w_1	1.399	.....	Diffuse
5447.130	5	12 comps.	2,3	Pair IV, 0.874 (1)	Pair II, 0.447 (6)	2.946	1.507	*n*-comps. barely resolved
				Pair III, 0.701 (2)	Pair I, 0.226 (1)	2.363	0.762	
				Pair II, 0.477 (2)	.....	1.608	.....	
				Pair I, 0.219 (1)	.....	0.738	.....	
5455.834	4	Quintuple	2,3	0.347 (1)	0.680	1.163	2.283	Central line of *n* triplet displaced 0.009 Å toward red from no-field line
				0.000 (2)	.....	0.000	.....	
				0.345 (1)	.....	1.160	.....	
5463.494	1	Triple	1	0.565	.....	1.893	.....	Very faint
5474.113	1	Triple	1	0.686	.....	2.289	.....	Very faint
5476.500	1	Triple	..	n.m.	.....	.....	.....	
5476.778	1	Triple	2	0.647	.....	2.157	.....	
5487.959	1	Quadruple?	..	n.m.	w_2	.....	.....	Very faint
5497.735	3	Octuple	2,2	0.683 (4)	0.346 (2)	2.260	1.144	
				0.352 (2)	0.000 (3)	1.165	0.000	
				0.000 (1)	0.341 (2)	0.000	1.128	
				0.340 (2)	.....	1.127	.....	
				0.706 (4)	.....	2.338	.....	
5501.683	3	Sextuple?	2	1.001 w_2	w_2	3.307	.....	Appears as diffuse triplet. All comps. doubtless compound
5507.000	3	9 comps.?	2	1.026 w_2	w_2	3.383	.....	Probably 6 *n*-, 3 *p*-comps. Outer *n*-comps. strongest
5535.644	1	Triple	1	0.437	.....	1.427	.....	Blend with air line
5555.122	1	Sextuple?	1	0.502 w_1	w_2	1.628	.....	Weak and diffuse
5563.824	1	Triple	2	0.652	.....	2.107	.....	Faint
5565.931	1	Sextuple?	1	0.478 w_1	w_1	1.542	.....	Comps. diffuse
5569.848	2	Septuple?	2	0.335 w_2	w_2	1.080	.....	*n*-comps. fringed. At least 3 *p*-comps.
5573.075	3	Septuple?	2	0.469 w_2	w_2	1.511	.....	*n*-comps. fringed. At least 3 *p*-comps.
5576.320	1	Unaffected						
5586.991	5	Septuple?	2	0.510 w_2	w_2	1.634	.....	*n*-comps. fringed. Probably 3 close *p*-comps.
5598.524	1	Triple	..	n.m.	.....	.....	.....	Very faint
5603.186	1	Quintiple	2,2	0.372 (1)	0.728	1.186	2.318	Compare 5455.834
				0.000 (2)	.....	0.000	.....	
				0.343 (1)	.....	1.092	.....	
5615.877	6	Triple	2	0.586	.....	1.859	.....	
5624.769	1	Sextuple?	1,2	0.664 w_2	0.481	2.098	1.520	
5638.488	1	Sextuple?	..	n.m. w_2	w_2	.....	.....	Faint and diffuse
5659.052	1	Sextuple?	2,2	0.724 w_2	0.307 w_1	2.259	0.960	*n*-comps. diffuse
5662.744	1	Triple?	2	0.596	w_1	1.858	....	Faint
5693.865	4	Triple	..	n.m.	.....	.....	.....	Very faint
5701.772	1	Triple	2	0.607	.....	1.867	.....	
5706.215	1	Triple?	2	0.605 w_1	w_1	1.858	.....	
5709.601	1	Quadruple?	2	0.785 w_1	w_2	2.408	.....	*p*-comp. almost resolved
5718.055	1	Triple	2	0.383	.....	1.172	.....	
5731.984	1	Sextuple?	1	0.631 w_1	w_2	1.920	.....	Comps. diffuse
5752.254	1	Sextuple?	..	n.m. w_2	w_2	.....	.....	Comps. diffuse
5753.344	1	Triple	2	0.575	.....	1.737	.....	
5763.218	1	Triple	3	0.631	.....	1.900	.....	
5775.304	1	Sextuple?	1	0.762 w_1	w_2	2.279	.....	Comps. diffuse
5816.601	1	?	1	0.442 w_2	w_2	1.306	.....	Probably numerous *n*-comps. Very diffuse

TABLE 1.—MEASUREMENTS OF ZEEMAN EFFECT FOR IRON—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	$\Delta\lambda$		$\Delta\lambda/\lambda^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
5856.312	1	Triple	..	n.m.	.....	.....	.....	Very faint
5859.809	1	Sextuple?	2	0.698 w_1	w_2	2.033	.....	
5862.582	1	Triple	2	0.684	.....	1.990	.....	
5884.028	1	Triple	2	0.436	.....	1.259	.....	
5905.895	1	?	..	w_2	w_2	.....	.....	*n*-comps. not resolved
5914.335	1	Quadruple?	2	0.658 w_1	w_2	1.880	.....	
5930.406	1	Triple?	2	0.587 w_1	w_1	1.669	.....	
5934.881	1	Triple	2	0.589	.....	1.672	.....	
5952.943	1	Triple?	..	n.m.	.....	.....	.....	Blend with air line
5975.575	1	?	..	n.m.	w_2	.....	.....	*n*-comps. very diffuse
5977.007	1	Triple	2	0.635	.....	1.777	.....	
5983.908	1	Triple?	1	0.608 w_1	w_1	1.698	.....	
5985.040	1	Triple	2	0.662	.....	1.848	.....	
5987.290	1	Triple?	1	0.624	w_1	1.740	.....	
6003.239	1	Triple	2	0.772	.....	2.142	.....	
6008.785	1	Triple	2	0.652	.....	1.806	.....	
6020.401	1	Triple?	2	0.845 w_1	w_1	2.332	.....	Diffuse
6024.281	1	Triple	2	0.649	.....	1.788	.....	
6027.274	1	Triple	2	0.568	.....	1.564	.....	
6042.315	1	?	..	n.m.	w_2	.....	.....	*n*-comp. blurred
6056.227	1	Sextuple?	1	0.499 w_2	w_2	1.361	.....	*n*-comps. diffuse. *p* almost resolved
6065.709	3	Triple	3	0.403	.....	1.095	.....	
6078.710	1	Triple?	2	0.635 w_1	w_1	1.718	.....	Faint
6102.392	1	Triple	..	n.m.	.....	.....	.....	Faint
6103.400	1	Sextuple?	–,2	n.m. w_2	0.583	.....	1.565	*n*-comps. very diffuse
6128.124	1	Sextuple?	1	0.414 w_2	w_2	1.102	.....	Faint and diffuse
6136.829	5	Triple	3	0.515	.....	1.367	.....	
6137.915	5	Triple	3	0.654	.....	1.736	.....	
6141.938	1	Triple?	2	1.017	w_1	2.696	.....	Faint
6148.040	1	Sextuple?	1	0.649 w_2	w_1	1.717	.....	Very diffuse
6149.458	1	Quadruple	1,1	0.812	0.740	2.148	1.950	Enhanced line
6157.945	1	Triple?	2	0.719	w_1	1.896	.....	
6165.577	1	Sextuple?	..	n.m. w_2	w_2	.....	.....	*n*-comps. diffuse
6170.730	1	Sextuple?	2	0.725 w_2	w_2	1.904	.....	*p*-comp. almost resolved
6173.553	1	Triple	2	1.590	.....	4.171	.....	Difficult. Blend with air band
6180.420	1	Triple?	..	n.m.	w_1	.....	.....	Faint
6188.210	1	Triple	..	n.m.	.....	.....	.....	Faint
6191.779	5	Triple	3	0.541	.....	1.411	.....	
6200.527	1	Sextuple?	1	1.026 w_2	w_2	2.669	.....	Comps. diffused
6213.644	1	Sextuple	2,3	Pair II, 1.603 (1)	0.572	4.151	1.481	
				Pair I, 0.798 (1)	.....	2.067	.....	
6215.360	1	Triple	2	0.583	.....	1.509	.....	
6219.494	1	Sextuple?	2,2	0.991 w_2	0.385	2.562	0.995	
6230.943	6	Triple	3	0.767	.....	1.976	.....	
6232.856	1	Sextuple?	2	1.205 w_1	w_2	3.102	.....	
6238.598	1	Sextuple?	1,1	1.042 w_1	0.512	2.677	1.315	Enhanced line
6246.535	2	Sextuple?	2,2	0.958 w_1	0.278	2.456	0.713	
6247.774	1	Septuple?	1	0.670 w_2	w_2	1.716	.....	Enhanced line. *n*-comps. very diffuse. Probably 3 *p*-comps.
6252.773	3	Triple	3	0.582	.....	1.488	.....	
6254.456	1	Triple	3	0.952	.....	2.434	.....	
6256.572	1	Sextuple?	–,2	n.m. w_2	0.696	.....	1.778	*n*-comps. very diffuse
6265.348	1	Sextuple?	2,2	0.969 w_2	0.278	2.469	0.708	
6270.442	1	Triple?	..	n.m.	w_1	.....	.....	Very faint
6291.184	1	Sextuple?	1	1.014	w_2	2.562	.....	
6298.007	1	Sextuple?	..	n.m. w_2	w_2	.....	.....	
6301.718	3	Sextuple?	2,2	1.063 w_2	0.392	2.676	0.987	*n*-comps. probably double
6302.709	1	Triple	2	1.618	.....	4.073	.....	
6315.517	1	Sextuple?	1	0.906 w_1	w_2	2.271	.....	Faint. *p*-comp. almost resolved. Enhanced line
6318.239	3	Triple	2	0.452	.....	1.132	.....	
6322.907	1	Triple	2	0.965	.....	2.414	.....	
6331.067	1	Sextuple?	1	0.820 w_2	w_1	2.046	.....	Very faint
6335.554	3	Septuple?	2	0.665 w_2	w_2	1.656	.....	Probably 3 *p*-comps.
6337.048	3	Sextuple	2,2	Pair II, 1.641 (1)	0.632	4.086	1.574	
				Pair I, 0.946 (1)	.....	2.356	.....	

TABLE 1.—MEASUREMENTS OF ZEEMAN EFFECT FOR IRON—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	Δλ		Δλ/λ²		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
6339.096	1	Triple?	..	n.m.	.....	.....	.....	Very faint
6344.371	1	Sextuple?	1	0.771 w_1	n.m.	1.916	.....	Very faint. *p*-comp. double
6355.246	1	Triple	1	0.730	.....	1.808	.....	Very faint
6358.898	1	Sextuple?	1	0.746 w_2	w_1	1.845	.....	Very faint
6380.958	1	Triple	1	0.464	.....	1.140	.....	Enhanced line
6393.820	8	Triple	2	0.593	.....	1.450	.....	
6400.217	9	Septuple?	2	0.802 w_1	w_2	1.958	.....	*n*-comps. slightly fringed. Probably 3 close *p*-comps.
6408.233	1	Septuple?	–,2	n.m.	0.343 (1) 0.000 (2) 0.349 (1)	....	0.837 0.000 0.852	Apparently 4 weak *n*-comps. about equally spaced
6411.865	5	Septuple?	2	0.686 w_2	w_3	1.668	.....	*n*-comps. fringed, probably 3 *p*-comps.
6417.133	1	?	1	1.018 w_2	w_3	2.472	.....	*n*- and *p*-comps. very diffuse. Enhanced line
6420.169	1	Sextuple?	1	0.743 w_2	w_2	1.802	.....	*n*-comps. diffuse. Enhanced line
6421.570	2	Triple	3	0.993	.....	2.408	.....	
6431.066	3	Sextuple?	2	0.775 w_1	w_1	1.873	.....	
6436.630	1	Triple?	1	0.840 w_1	w_1	2.027	.....	Diffuse
6456.603	1	Sextuple?	2	0.781 w_1	w_2	1.873	.....	Enhanced line. Possibly diffuse triplet
6462.965	1	Sextuple?	–,2	n.m.	0.585	.....	1.400	*n*-comps. faint and diffuse
6469.408	1	?	..	n.m.	w_2	.....	.....	Very faint
6475.846	1	?	..	n.m.	w_2	.....	.....	Very faint
6495.213	3	Triple	3	0.682	.....	1.617	.....	
6518.599	1	Triple	1	0.837	.....	1.970	.....	Very faint
6546.479	1	Triple	2	0.584	.....	1.363	.....	
6569.460	1	Triple	1	0.921	.....	2.134	.....	Close to air line. Enhanced line
6575.270	1	Sextuple?	..	n.m. w_2	n.m.	.....	.....	*p*-comp. apparently double. Very faint
6593.161	3	Triple	3	0.699	.....	1.608	.....	
6594.121	1	Sextuple?	–,2	n.m. w_1	0.579	.....	1.332	Very faint
6627.797	1	Triple?	..	n.m.	w_1	.....	.....	Very faint. Enhanced line
6633.995	1	Triple	..	n.m.	.....	.....	.....	Very faint
6663.701	1	Triple	2	1.088	.....	2.443	.....	Enhanced line
6678.235	3	Triple	3	0.787	.....	1.765	.....	

TABLE 2.—MEASUREMENTS OF ZEEMAN EFFECT FOR TITANIUM.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	Δλ		$\Delta\lambda/\lambda^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
3659.901	10	Triple	2	0.243	.....	1.814	.....	
3660.774	2	Quadruple?	–,2	n.m.	0.188	.....	1.403	
3662.378	10	Triple	2	0.199	.....	1.484	.....	
3669.106	2	Triple	..	n.m.				
3671.819	3	Quadruple?	–,2	n.m.	0.161	.....	1.194	
3679.821	3	Quadruple?	..	n.m.	w_2			
3685.339	20	Triple	2	0.232	.....	1.708	.....	Enhanced line
3690.053	2	Triple	..	n.m.				
3706.363	8	Quadruple?	2,3	0.201 w_1	0.139	1.463	1.012	Enhanced line
3710.094	2	Quadruple?	..	n.m. w_2	w_2	.....	.....	
3717.539	2	Quadruple?	..	n.m. w_2	w_2	.....	.....	
3721.779	5	Quadruple?	3	0.344	w_2	2.483	.....	Enhanced line
3722.729	3	Triple?	1	0.145	w_1	1.046	.....	*n*-comps. faint
3724.716	3	Triple	2	0.243	.....	1.751	.....	
3725.300	3	Triple?	1	0.261	w_1	1.881	.....	*n*-comps. faint
3729.952	4	Triple	3	0.142	.....	1.021	.....	
3741.205	2	Triple	3	0.248	.....	1.772	.....	
3741.791	10	Triple	3	0.263	.....	1.878	.....	Enhanced line
3748.232	6	Triple	2	0.190	.....	1.352	.....	Enhanced line
3753.003	5	Triple	3	0.277	.....	1.967	.....	
3753.732	3	Quadruple?	2	0.374	w_2	2.654	.....	
3757.824	6	Triple	2	0.199	.....	1.409	.....	Enhanced line
3759.447	20	Triple	2	0.288	.....	2.038	.. ..	Enhanced line
3761.464	10	Triple	2	0.207	.....	1.463	.....	Enhanced line
3762.012	3	Triple	3	0.253	.....	1.788	.....	Enhanced line
3771.798	3	Triple?	2	0.356	w_1	2.502	.....	
3776.198	4	Triple?	2	0.336	w_1	2.357	.....	Enhanced line
3786.181	3	Triple	3	0.229	.....	1.598	.....	
3813.537	3	Quadruple?	2	0.288 w_1	w_1	1.980	.....	Enhanced line
3814.671	3	Sextuple?	2	0.319 w_2	w_2	2.192	.....	Enhanced line
3836.229	3	Triple?	2	0.341	w_1	2.317	.....	Enhanced line
3853.872	2	Triple?	2	0.267	w_1	1.798	.....	
3858.262	2	Triple?	2	0.278	w_1	1.868	.....	
3866.577	2	Triple	2	0.284	.....	1.900	.....	
3868.539	2	Triple?	2	0.343	w_1	2.292	.....	
3875.425	2	Triple	2	0.322	.....	2.144	.....	
3882.309	2	Triple	2	0.325	.....	2.157	.....	
3882.439	4	Sextuple?	2	0.399 w_1	w_2	2.648	.....	
3883.033	3	Triple	2	0.279	.....	1.850	.....	
3895.377	2	Triple?	2	0.309	w_1	2.037	.....	
3900.681	50	Triple	3	0.272	.....	1.787	.....	Enhanced line
3904.926	5	Triple	3	0.240	.....	1.574	.....	
3913.609	20	Triple	3	0.219	.....	1.430	.....	Enhanced line
3914.477	2	Sextuple?	2,3	0.352 w_2	0.206	2.298	1.345	
3921.563	2	11 comps.?	1,–	0.340 (1)	n.m.	2.210	.....	Probably two pairs *p*-comps. Compare λ 3930.022
				0.224 (3)	.....	1.456	.....	
				0.100 (2)	.....	0.650	.....	
				0.000 (3)	.....	0.000	.....	
				0.097 (2)	.....	0.631	.....	
				0.198 (3)	.....	1.287	.....	
				0.320 (1)	.....	2.080	.....	
3924.673	3	Octuple?	2,3	0.292 w_2	0.162	1.895	1.052	Probably 3 pairs *n*-comps.
3926.465	2	Triple	3	0.247	.....	1.602	.....	
3930.022	3	11 comps?	2,3	0.264 (1)	0.292	1.709	1.890	Trace of inner pair *p*-comps. Compare λ 3921.563
				0.187 (3)	.....	1.211	.....	
				0.095 (2)	.....	0.615	.....	
				0.000 (3)	.....	0.000	.....	
				0.094 (2)	.....	0.609	.....	
				0.178 (3)	.....	1.152	.....	
				0.267 (1)	.....	1.729	.....	
3932.161	4	?	2	0.406 w_2	w_2	2.626	.....	Enhanced line. *n*-comps. have strong inner fringes
3947.918	3	?	2	0.098 w_2	w_2	0.629	.....	*n*-comps. strongly fringed
3948.818	4	Triple	3	0.186	.....	1.193	.....	
3956.476	4	Sextuple?	2	0.229 w_1	w_1	1.463	.....	*n*-comps. fringed
3958.355	5	Triple	3	0.287	.....	1.832	.....	
3962.995	3	?	2	0.461 w_2	w_2	2.935	.....	*n*-comps. have strong inner fringes, similar to λ 3932.161

TABLE 2.—MEASUREMENTS OF ZEEMAN EFFECT FOR TITANIUM—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	$\Delta\lambda$		$\Delta\lambda/\lambda^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
3964.416	3	Sextuple?	2	0.359 w_1	w_1	2.285	.....	Probably inner pair *n*-comps.
3981.917	3	Triple	2	0.188	.....	1.186	.....	
3982.142	2	Sextuple	2,2	Pair II, 0.390 (1)	0.311	2.460	1.961	
				Pair I, 0.151 (1)	.....	0.952	.....	
3982.630	3	10 comps.?	2,1	Pair III, 0.784 (1)	0.565	4.942	3.561	Probably weak inner pair *p*-comps. Difficult blend with two preceding lines
				Pair II, 0.475 (2)	.....	2.994	.....	
				Pair I, 0.148 (4)	.....	0.933	.....	
3987.755	1	Triple	..	n.m.	.....	.....	.....	Enhanced line
3989.912	6	Triple	3	0.275	.....	1.727	.....	
3998.790	6	Triple	3	0.317	.....	1.720	.....	Unsymmetrical. *n*-comps. have inner fringes, broader for violet comp. *p*-comp. fringed toward violet
4009.079	4	Sextuple?	2	0.347 w_2	w_2	2.159	.....	
4009.807	2	?	2	0.086	?	0.535	.....	Unsymmetrical. Violet *n*-comp. 3 times strength of red. *p*-comp. hazy, displaced toward violet
4012.541	4	Octuple?	2,3	0.198 w_2	0.169	1.230	1.050	Enhanced line. Probably 3 pairs *n*-comps.
4021.893	2	?	..	n.m.	.....	.....	.....	*n*-comps. diffuse, narrowly separated. *p*-comp. fairly sharp
4024.726	3	Sextuple?	2	0.394 w_1	w_1	2.432	.....	*n*-comps. have inner fringes
4025.286	3	Sextuple?	2,3	0.263 w_2	0.129	1.623	0.796	Enhanced line
4026.691	2	Triple	2	0.220	.....	1.357	.....	
4028.497	5	Triple	3	0.269	.....	1.658	.....	Enhanced line
4030.646	2	Triple?	2	0.243 w_1	w_1	1.495	.....	
4035.976	2	Triple	2	0.354	.....	2.173	.....	
4053.981	5	Triple	3	0.232	.....	1.412	.....	Enhanced line
4055.189	3	Triple	3	0.395	.....	2.402	.....	Enhanced line
4060.415	3	Triple	3	0.395	.....	2.396	.....	
4064.362	2	Triple	3	0.396	.....	2.398	.....	
4065.239	3	Triple	3	0.395	.....	2.390	.....	
4078.631	4	Triple	3	0.395	.....	2.374	.....	
4082.589	3	Triple	3	0.398	.....	2.388	.....	
4112.869	2	Sextuple?	1,2	0.301 w_2	0.236	1.779	1.395	*n*-comps. very diffuse
4122.306	2	Triple	2	0.261	.....	1.536	.....	
4123.713	2	Triple	2	0.264	.....	1.552	.....	
4127.689	3	Triple	2	0.291	.....	1.708	.....	
4137.428	2	Triple	2	0.365	.....	2.133	.....	
4151.129	3	Triple	3	0.305	.....	1.770	.....	
4159.805	2	Triple	2	0.263	.....	1.520	.....	
4161.682	3	Sextuple?	2	0.495 w_2	w_2	2.858	.....	Enhanced line. *n*-comps. have inner fringes
4163.818	20	Triple	3	0.294	.....	1.696	.....	Enhanced line
4171.213	2	Triple	2	0.210	.....	1.207	.....	
4172.066	15	Triple	3	0.251	.....	1.442	.....	Enhanced line
4173.710	3	Sextuple?	2,2	0.361 w_1	0.096	2.072	0.551	Enhanced line
4184.472	1	?	..	n.m. w_2	w_2	.....	.....	Enhanced line, all comps. diffuse
4186.280	3	Triple	3	0.282	.....	1.609	.....	
4200.946	2	Triple?	1	0.463	w_1	2.623	.....	Faint in spark
4203.620	2	Triple	1	0.457	.....	2.586	.....	Faint in spark
4238.050	2	Triple	2	0.286	.....	1.592	.....	
4256.760	2	Sextuple?	2	0.396 w_1	.....	2.186	.....	
4261.748	2	Triple?	2	0.324 w_1	w_1	1.784	.....	
4263.290	4	Triple	3	0.331	.....	1.821	.....	
4270.329	2	Sextuple?	2,2	0.378 w_2	0.248	2.073	1.360	
4272.701	2	Septuple?	2	0.364 w_2	w_2	1.994	.....	λ given by Fiebig as 4272.581 agrees better with solar line λ4272.590. *n*-comps. have inner fringes. Probably 3 *p*-comps.
4274.746	4	Triple	3	0.291	.....	1.572	.....	
4276.587	2	Sextuple?	2	0.443 w_1	w_2	2.422	.....	*n*-comps. have inner fringes
4278.390	2	Triple	3	0.304	.....	1.661	.....	

TABLE 2.—MEASUREMENTS OF ZEEMAN EFFECT FOR TITANIUM—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	Δλ		$\Delta\lambda/\lambda^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
4281.530	2	Octuple	3,3	0.444 (4) 0.218 (2) 0.000 (1) 0.218 (2) 0.448 (4)	..... 0.222 (2) 0.000 (3) 0.224 (2)	2.422 1.189 0.000 1.189 2.443	..... 1.211 0.000 1.222	
4282.860	3	Triple	3	0.244	.....	1.330	.....	
4285.164	5	Quadruple?	3	0.566	w_1	3.083	.....	
4286.168	4	Sextuple?	2,3	0.400 w_2	0.166	2.177	0.904	
4287.566	4	Sextuple?	2,3	0.421 w_2	0.146	2.290	0.794	
4288.038	2	Septuple?	2	0.516 w_1	w_3	2.806	.....	*n*-comps. have inner fringes. Probably 3 *p*-comps.
4289.237	4	12 Comps.	2,3	Pair IV, 0.586 (1) Pair III, 0.443 (2) Pair II, 0.306 (2) Pair I, 0.144 (1)	Pair II, 0.288 (6) Pair I, 0.140 (1)	3.186 2.408 1.663 0.783	1.566 0.761	
4290.377	10	?	2	0.284 w_2	w_3	1.543	.....	*n*-comps. strongly fringed. 3 or more *p*-comps. Enhanced line
4291.114	2	Quintuple	3,3	0.221 (1) 0.000 (2) 0.220 (1)	0.445	1.200 0.000 1.195	2.417	
4291.375	2	Triple	1	0.230	.....	1.249	.....	Difficult blend with 4291.114
4294.204	10	Triple	3	0.361	.....	1.958	.....	Enhanced line
4295.914	4	Unaffected						
4298.828	4	Septuple	2,3	Pair II, 0.292 (1) Pair I, 0.145 (5)	0.060 (2) 0.000 (3) 0.086 (2)	1.580 0.784	0.325 0.000 0.465	*p*-comps. distinctly unsymmetrical
4299.410	3	Quadruple?	1	0.430	w_2	2.327	.....	
4299.803	2	Triple?	1	0.356	w_1	1.925	.....	
4300.211	8	?	2	0.367 w_1	w_2	1.985	.....	*n*-comps. fringed. 3 or more *p*-comps. Enhanced line
4300.732	2	Septuple?	2	0.265 w_1	w_2	1.432	.....	*n*-comps fringed, probably 3 *p*-comps.
4301.158	3	Triple?	3	0.350	w_1	1.892	.....	
4302.085	5	Sextuple	3,3	Pair II, 0.585 (1) Pair I, 0.151 (3)	0.216	3.161 0.816	1.167	Enhanced line
4306.078	8	Septuple?	2	0.367 w_1	w_2	1.979	.....	*n*-comps. fringed, probably 3 *p*-comps.
4308.081	8	Octuple	2,2	Pair III, 0.588 (1) Pair II, 0.442 (2) Pair I, 0.291 (3)	0.236	3.168 2.382 1.568	1.272	Blend with iron impurity line probably gives apparent dissymmetry in intensity of *n*-comps. Enhanced line
4311.880	1	Sextuple?	2	0.147	w_1	0.791	.....	Outer pair *n*-comps. not measurable. Possibly 3 *p*-comps. Blend with faint lines
4313.034	8	Sextuple?	2,2	0.449 w_2	0.159	2.414	0.855	Enhanced line
4314.964	3	Triple	3	0.424	.....	2.277	.....	
4315.138	5	Quadruple	3,3	0.392	0.349	2.105	1.874	Enhanced line
4316.962	2	Triple	3	0.207	.....	1.111	.....	Enhanced line
4318.817	3	Triple	3	0.337	.....	1.807	.....	
4321.119	3	Sextuple	3,3	Pair II, 0.785 (2) Pair I, 0.257 (1)	0.261	4.204 1.376	1.398	Enhanced line
4321.813	3	Triple	3	0.310	.....	1.660	.....	
4323.531	1	Triple	2	0.464	.....	2.482	.....	
4325.306	3	Triple	3	0.301	.....	1.609	.....	
4326.520	2	Triple	3	0.403	.....	2.152	.....	
4330.405	3	Sextuple?	2	0.415 w_1	w_2	2.213	.....	Enhanced line
4330.866	3	?	2	0.654 w_2	w_3	3.487	.....	Enhanced line. *n*-comps. have inner fringes
4338.084	10	Triple	3	0.247	.....	1.312	.....	Enhanced line
4341.530	3	?	..	w_3	w_2	.....	.....	Enhanced line. Probably numerous close *n*-comps, not resolved, center strong
4344.451	3	Sextuple?	2	0.474 w_2	w_2	2.512	.....	Enhanced line
4346.278	2	Sextuple?	2	0.453 w_1	w_2	2.398	.....	
4351.000	2	Triple	3	0.387	.....	2.044	.....	Enhanced line
4354.228	2	Quadruple?	2	0.300 w_1	w_1	1.583	.....	
4360.644	2	Triple	3	0.348	.....	1.830	.....	

TABLE 2.—MEASUREMENTS OF ZEEMAN EFFECT FOR TITANIUM—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	Δλ		Δλ/λ²		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
4367.839	6	Triple	3	0.332	.....	1.740	.....	Enhanced line
4369.873	2	Triple	3	0.306	.....	1.602	.....	
4372.498	2	Triple	3	0.314	.....	1.643	.....	
4374.981	3	Triple	3	0.334	.....	1.745	.....	Enhanced line
4387.007	5	Triple	3	0.294	.....	1.528	.....	Enhanced line
4391.192	2	Septuple?	2	0.304 w_2	w_2	1.577	.....	Enhanced line. Probably 4 *n*-, 3 *p*-comps.
4394.093	2	Triple	2	0.325	.....	1.683	.....	
4394.225	2	Triple	2	0.420	.....	2.175	.....	
4395.201	20	Triple	3	0.347	.....	1.796	.....	Enhanced line
4396.008	2	Triple?	3	0.374	w_1	1.935	.....	Enhanced line
4398.460	1	Quadruple?	2,3	0.144	0.224	0.744	1.158	Possibly faint outer *n*-comps, but not visible on strong photograph
4399.935	6	Triple	3	0.431	.....	2.226	.....	Enhanced line
4404.433	4	Triple	2	0.411	.....	2.119	....	
4405.082	1	Triple	1	0.316	.....	1.628	.....	
4405.896	1	Sextuple?	–,3	n.m. w_2	0.314	.....	1.617	
4409.408	1	Sextuple?	1,1	0.523 w_1	0.171	2.690	0.880	
4409.683	1	Sextuple?	–,1	n.m. w_2	0.248	.....	1.275	
4411.240	5	Triple	3	0.291	.....	1.496	.....	Enhanced line
4417.450	2	Triple	3	0.381	.....	1.953	.....	
4417.884	6	10 comps.?	2,2	Pair II, 0.288 (1)	Pair II, 0.240 (2)	1.476	1.230	Probably weak pair *n*-comps. outside. Enhanced line
				Pair I, 0.120 (2)	Pair I, 0.072 (3)	0.615	0.369	
4418.499	2	Sextuple?	2	0.402 w_1	w_1	2.060	.....	
4421.928	2	Triple	2	0.289	.....	1.478	.....	Enhanced line, blend
4422.104	2	Quadruple?	2,1	0.358 w_1	0.107	1.831	0.547	
4422.985	2	Triple	3	0.377	.....	1.927	.....	
4424.531	1	Triple	2	0.304	.....	1.553	.....	
4426.201	2	Triple	3	0.318	.....	1.623	.....	
4427.266	4	Triple	3	0.312	.....	1.592	.....	
4430.524	2	Sextuple?	2	0.468 w_1	w_2	2.384	.....	*n*-comps have inner fringes
4431.453	1	Triple	2	0.154	.....	0.784	.....	
4433.742	1	Triple	3	0.187	.....	0.951	.....	
4434.168	3	Triple	3	0.259	.....	1.317	.....	
4436.750	2	Sextuple?	2	0.466 w_1	w_2	2.367	.....	
4438.359	1	Sextuple?	1,2	0.441 w_2	0.180	2.239	0.914	
4440.515	2	Sextuple?	2,3	0.270 w_1	0.168	1.369	0.852	
4441.433	1	Quadruple?	1	0.413 w_1	w_2	2.094	.....	
4443.976	15	Triple	3	0.298	.....	1.509	.....	Enhanced line
4444.728	1	Sextuple?	2,2	0.317 w_2	0.245	1.604	1.240	
4449.313	5	Triple	3	0.388	.....	1.960	.....	
4450.654	4	10 comps.?	2,3	0.388 w_2	0.264 w_1	1.958	1.333	Probably 6 *n*-, 4 *p*-comps. Enhanced line
4451.087	3	Triple	3	0.340	.....	1.716	.....	
4453.486	3	Triple	3	0.210	.....	1.059	.....	
4453.876	3	Quadruple ?	3	0.263	w_1	1.326	.....	
4455.485	4	Triple	3	0.351	.....	1.768	.....	
4457.600	5	Triple	3	0.400	.....	2.013	.....	
4463.569	1	Quadruple ?	1	0.509 w_1	w_2	2.554	.....	
4463.843	1	Triple ?	1	0.509	w_1	2.554	.....	
4464.617	2	Quintuple	2,3	0.285 (1)	0.287	1.430	1.440	Enhanced line
				0.000 (5)	.....	0.000	.....	
				0.262 (1)	.....	1.314	.....	
4465.975	3	Quadruple?	3	0.481 w_1	w_1	2.412	.....	
4468.663	15	Triple	3	0.340	.....	1.702	.....	Enhanced line
4469.316	1	Triple	2	0.426	.....	2.133	.....	
4471.017	2	10 comps.?	2,2	Pair III, 0.724 (1)	0.458	3.622	2.292	Trace of inner pair *p*-comps.
				Pair II, 0.386 (1)	.....	1.931	.....	
				Pair I, 0.126 (1)	.....	0.630	.....	
4471.408	2	9 comps.	2,2	Pair III, 0.826 (1)	0.113 (2)	4.132	0.565	
				Pair II, 0.613 (2)	0.000 (3)	3.066	0.000	
				Pair I, 0.364 (4)	0.116 (2)	1.821	0.580	
4475.026	2	Septuple?	2	0.509 w_1	w_2	2.542	.....	Probably 4 *n*-, 3 *p*-comps.
4479.879	2	Triple	3	0.829	.....	4.130	.....	
4480.752	1	Triple	2	0.611	.....	3.043	.....	
4481.438	3	Triple	3	0.548	.....	2.729	.....	
4482.904	2	Sextuple?	2	0.498 w_1	w_2	2.478	.....	

TABLE 2.—MEASUREMENTS OF ZEEMAN EFFECT FOR TITANIUM—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	Δλ		$Δλ/λ^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
4488.493	6	Triple	3	0.355	.....	1.762	.....	Enhanced line
4489.262	3	9 comps.	2,2	Pair III, 0.858 (1)	0.111 (2)	4.258	0.551	Compare λ 4471.408
				Pair II, 0.597 (2)	0.000 (3)	2.963	0.000	
				Pair I, 0.382 (4)	0.110 (2)	1.896	0.546	
4495.182	1	Triple	1	0.353	.....	1.747	.....	
4496.318	3	Triple	3	0.493	.....	2.439	.....	
4497.842	1	Triple	2	0.534	.....	2.639	.....	
4501.445	15	Triple	3	0.298	.....	1.471	.....	Enhanced line
4512.906	4	Triple	3	0.501	.....	2.460	.....	
4518.198	4	Quadruple?	3	0.498	w_1	2.440	.....	
4518.866	1	Triple	2	0.220	.....	1.077	.....	
4522.974	4	Sextuple?	3	0.502 w_1	w_2	2.454	.....	
4527.490	4	Octuple	3,3	0.324 (7)	0.164 (1)	1.581	0.800	
				0.162 (2)	0.000 (2)	0.790	0.000	
				0.000 (1)	0.165 (1)	0.000	0.805	
				0.166 (4)	.....	0.810	.....	
				0.338 (7)	.....	1.649	.....	
4529.656	2	Sextuple?	2,2	0.358 w_2	0.278 w_1	1.745	1.355	Enhanced line
4533.419	5	Triple	3	0.469	.....	2.282	.....	
4534.139	6	Triple?	2	0.360 w_1	w_1	1.751	.....	*n*-comps. slightly fringed. Enhanced line
4534.953	4	Triple	3	0.449	.....	2.183	.....	
4535.741	3	Triple	3	0.424	.....	2.061	.....	
4536.094	3	Triple	2	0.323	.....	1.570	.....	
4536.222	3	Unaffected?		.....	.....	.....	.....	No resolution. Blend with 36.094 may conceal slight widening of *n*-comp.
4537.389	1	Triple	1	0.355	.....	1.725	.....	
4544.190	1	Quadruple?	1	0.308	w_2	1.492	.....	
4544.864	3	Octuple	3,3	0.334 (7)	0.171 (1)	1.617	0.828	Comps. in all respects similar to λ 4427.490
				0.168 (2)	0.000 (2)	0.813	0.000	
				0.000 (1)	0.166 (1)	0.000	0.804	
				0.170 (4)	.....	0.823	.....	
				0.332 (7)	.....	1.607	.....	
4548.938	3	Septuple?	2	0.560 w_1	w_2	2.706	.. ..	*n*-comps. have inner fringes. Probably 3 *p*-comps.
4549.808	20	Triple	3	0.440	.....	2.125	.....	Enhanced line
4552.632	4	Quadruple?	3	0.510	w_1	2.460	.....	
4555.662	3	Triple	3	0.506	.....	2.438	.....	
4560.102	1	Triple	2	0.446	.....	2.145	.....	
4562.814	1	Triple	3	0.424	.....	2.036	.....	
4563.939	10	Triple	3	0.276	.....	1.325	.....	Enhanced line
4568.499	1	Quintuple?	–,2	n.m.	0.293	.. ..	1.404	Only central *n*-comp. visible. Line probably similar to λ 4464.617
4571.095	1	Triple	2	0.221	.....	1.058	.....	
4572.156	20	Triple	3	0.319	.....	1.526	.....	Enhanced line
4590.126	3	Octuple	2,3	Pair III, 0.549 (2)	0.288	2.606	1.367	6 *n*-comps. not completely resolved
			..	Pair II, 0.360 (3)	.....	1.709	.....	
				Pair I, 0.165 (2)	.....	0.783	.....	Enhanced line
4599.408	1	Triple	3	0.423	.....	2.000	.....	
4617.452	4	Septuple?	2	0.404 w_1	w_2	1.895	.....	*n*-comps. fringed. Probably 3 *p*-comps
4623.279	3	Septuple?	2	0.379 w_2	w_2	1.773	.....	*n*-comps. fringed. Probably 3 *p*-comps.
4629.521	2	9 comps.	3,3	Pair III, 0.873 (1)	0.172 (2)	4.072	0.802	
				Pair II, 0.535 (2)	0.000 (3)	2.496	0.000	
				Pair I, 0.173 (4)	0.180 (2)	0.807	0.840	
4638.050	1	Triple	3	0.528	.....	2.455	.....	
4639.538	2	Octuple?	2,2	0.594 w_2	0.224	2.759	1.040	Probably 3 pairs *n*-comps.
4639.846	2	Quadruple?	2	0.549	n.m.	2.550	.....	Blend prevents measurement of *p*-comps.
4640.119	2	Sextuple	3,3	Pair II, 0.864 (1)	0.353	4.013	1.640	
				Pair I, 0.535 (1)	.....	2.485	.....	
4645.368	2	Triple	3	0.880	.....	4.079	.....	Violet comp. 3/2 stronger than red
4650.193	2	Sextuple?	3	0.733 w_1	w_2	3.390	.....	

TABLE 2.—MEASUREMENTS OF ZEEMAN EFFECT FOR TITANIUM—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	$\Delta\lambda$		$\Delta\lambda/\lambda^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
4656.644	3	Triple	3	0.295	.....	1.360	.....	
4657.380	1	?	..	w_3	w_3	.....	.....	Not resolved. *n*-comp. has strong center with fringes. Enhanced line
4667.768	3	Triple	3	0.349	.....	1.602	.....	
4675.294	1	Triple	3	0.506	.....	2.315	.....	
4682.088	3	Triple	3	0.399	.....	1.820	.....	
4688.554	1	Triple	2	0.346	.....	1.574	.....	
4691.523	2	Triple?	3	0.441	w_1	2.003	.....	
4697.101	1	Triple	2	0.196	.....	0.888	.....	
4698.946	2	Sextuple?	2	0.367 w_2	w_2	1.662	.....	*n*-comps. fringed
4710.368	3	Quintuple	3	Pair II, 0.486 (1)	.....	2.191	.....	Single sharp *p*-comp. Only line of type in spectrum
				Pair I, 0.183 (1)	.....	0.825	.....	
4722.797	2	Sextuple	2,3	Pair II, 0.555 (1)	0.390	2.488	1.748	
				Pair I, 0.224 (1)	.....	1.004	.....	
4723.359	2	Sextuple?	2,2	0.453 w_2	0.226	2.031	1.013	*n*-comps. fringed
4731.356	2	Triple?	3	0.412	w_1	1.841	.....	
4733.604	2	Triple	2	0.350	.....	1.562	.....	
4742.979	5	Triple	3	0.295	.....	1.311	.....	
4758.308	8	Triple	3	0.382	.....	1.687	.....	
4759.463	8	Triple	3	0.430	.....	1.899	.....	
4764.108	1	Triple?		w_3	.....	.....	.....	Enhanced line. Unresolved *n*-comp. Diffuse
4769.991	1	Sextuple?	2	0.583 w_2	w_2	2.562	.....	
4778.441	3	Sextuple?	2,2	0.338 w_2	0.184	1.481	0.806	
4780.169	5	Quadruple	3,2	0.498	0.243	2.180	1.064	Enhanced line
4781.913	2	10 comps.?	–,1	n.m. w_3	0.314 w_2	.....	1.373	All comps. wide and hazy. Probably 3 pairs *n*-, 2 pairs *p*-comps.
4792.702	3	Sextuple?	2	0.370 w_2	w_2	1.611	.....	
4796.373	1	Triple?	2	0.195 w_1	.....	0.848	.....	
4798.169	1	Sextuple	1,2	Pair II, 0.594 (2)	0.388	2.580	1.685	
				Pair I, 0.218 (1)	.....	0.947	.....	
4798.293	1	?		w_3	w_2	.....	....	*n*-comps. diffuse, not resolved
4799.984	3	Sextuple?	2,2	0.329 w_2	0.182	1.428	0.790	
4805.285	10	Sextuple	2,2	Pair II, 0.643 (1)	0.149	2.785	0.645	Enhanced line
				Pair I, 0.364 (3)	.....	1.577	.....	
4805.606	5	Triple?	2	0.406	w_1	1.758	.....	
4808.733	2	Triple?	2	0.383 w_1	w_1	1.656	.....	
4811.235	1	Triple	2	0.398	.....	1.720	.....	
4820.593	4	Triple	3	0.390	.....	1.678	.....	
4827.804	1	Triple?	1	0.405	w_1	1.737	.....	
4836.313	2	Triple	3	0.364	.....	1.556	.....	
4841.074	6	Triple	3	0.390	.. ..	1.664	.....	
4848.605	2	Triple	3	0.516	.....	2.195	.....	
4856.203	7	Triple	3	0.416	.....	1.764	.....	
4864.362	1	Triple	2	0.441	.....	1.864	.....	
4865.798	1	Sextuple?	2	0.534 w_2	w_2	2.255	.....	Titanium?
4868.451	5	Triple	3	0.317	.....	1.338	.....	
4870.323	5	Triple	3	0.389	.....	1.640	.....	
4874.196	3	Triple	3	0.336	.....	1.414	.....	Enhanced line
4881.128	2	Triple	1	0.198	.....	0.831	.....	
4885.264	8	Triple	3	0.425	.....	1.781	.....	
4900.095	6	Triple	3	0.395	.....	1.645	.....	
4911.374	6	Triple?	3	0.434 w_1	w_1	1.799	.....	Enhanced line
4913.803	8	Triple	3	0.348	.....	1.441	.....	
4915.414	1	Sextuple?	2,2	0.415 w_2	0.234	1.718	0.969	
4920.047	3	Triple	3	0.387	.....	1.599	.....	
4921.963	3	Triple	3	0.439	.....	1.812	.....	
4925.594	1	Sextuple?	–,1	n.m. w_2	0.365	.....	1.504	
4926.334	1	Triple	1	0.509	.....	2.098	.....	
4928.511	3	Sextuple?	2	0.268 w_2	w_2	1.103	.....	
4938.467	3	Triple	3	0.392	.....	1.608	.....	
4968.769	1	Sextuple?	–,1	n.m. w_2	0.358	.....	1.450	
4975.530	1	Triple	3	0.414	.....	1.673	.....	
4978.372	1	Quadruple?	2	0.238 w_1	w_1	0.960	.....	
4981.912	10	Triple	3	0.481	.....	1.938	.....	
4989.325	2	Triple	3	0.329	.....	1.322	.....	

TABLE 2.—MEASUREMENTS OF ZEEMAN EFFECT FOR TITANIUM—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	$\Delta\lambda$		$\Delta\lambda/\lambda^2$		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
4991.247	10	Triple	3	0.458	.....	1.839	.....	
4997.283	2	?	–,3	n.m.	0.415	.....	1.662	Numerous *n*-comps. blurred. Red *n*- and *p*-comps. stronger than violet
4999.689	10	Triple	3	0.413	.....	1.652	.....	
5001.165	3	Triple?	3	0.405	w_1	1.619	.....	
5007.398	10	Triple	3	0.339	.....	1.352	.....	
5008.632	1	Triple	2	0.414	.....	1.650	.....	
5009.829	1	?	–,2	n.m.	0.279	.....	1.112	Numerous *n*-comps. blurred
5010.396	1	Triple?	2	0.354	w_1	1.410	.....	
5013.479	5	Triple	3	0.455	.....	1.811	.....	
5014.236	4	Triple	1	0.177	.....	0.704	.....	Titanium?
5014.369	5	Triple	2	0.217	.....	0.863	.....	
5016.340	7	Sextuple?	2,3	0.543	0.214	2.158	0.851	
5020.208	8	Octuple?	2,3	0.507 w_2	0.276	2.012	1.095	Probably 3 pairs *n*-comps.
5023.052	8	12 comps.?	2,3	0.466 w_2	0.370 w_1	1.847	1.466	Probably 4 pairs *n*-comps. *p*-comps. have inner fringes
5025.027	7	10 comps.	2,2	Pair III, 0.684 (1)	Pair II. 0.546 (6)	2.709	2.162	
				Pair II, 0.416 (2)	Pair I, 0.269 (1)	1.647	1.065	
				Pair I, 0.133 (4)	.....	0.527	.....	
5025.749	5	Triple	3	0.471	.....	1.865	.....	
5036.089	10	Triple	3	0.455	.....	1.794	.....	
5036.645	8	Triple	3	0.436	.....	1.718	.....	
5038.579	8	Triple	3	0.340	.....	1.339	.....	
5040.138	8	Triple	3	0.404	.....	1.590	.....	
5053.056	3	Triple?	2	0.449	w_1	1.759	.....	
5062.285	3	Triple?	2	0.412	w_1	1.608	.....	
5064.244	1	Triple		n.m.	.....	.....	.....	Very faint
5064.836	8	Triple	3	0.463	.....	1.805	.....	
5066.174	1	Sextuple?	–,1	n.m. w_2	0.407	.....	1.586	
5069.592	2	Triple	2	0.235	.....	0.914	.....	
5071.666	4	Sextuple?	1,1	0.470 w_2	0.275	1.827	1.069	
5072.479	6	Triple	3	0.502	.....	1.951	.....	Enhanced line
5087.239	4	Triple	3	0.329	.....	1.271	.....	
5113.617	5	Triple	3	0.431	.....	1.648	.....	
5120.592	7	Triple	3	0.434	.....	1.655	.....	
5129.336	8	Triple	3	0.478	.....	1.812	.....	Enhanced line
5145.636	6	Triple	3	0.493	.....	1.862	.....	
5147.652	5	Septuple?	2	0.805 w_2	w_2	3.038	.....	Probably more than 7 comps. *p*-comps. almost resolved
5152.361	5	Quadruple?	3	0.671 w_1	w_1	2.528	.....	
5154.244	4	Sextuple?	2	0.666 w_2	w_2	2.507	.....	Enhanced line
5173.917	10	Triple	2	0.292	.....	1.091	.....	
5186.073	8	Triple	3	0.385	.....	1.432	.....	Enhanced line
5188.863	12	Triple	3	0.512	.....	1.902	.....	Enhanced line
5193.139	10	Triple	3	0.468	.....	1.735	.....	
5201.260	3	Triple?	2	0.648 w_1	w_1	1.396	.....	
5206.215	4	Triple	2	0.470	.....	1.734	.....	
5210.555	10	Triple	3	0.547	.....	2.014	.....	
5219.875	4	Sextuple?	2	0.326 (2)	w_2	1.191	.....	Unsymmetrical. Probably 4 *n*-comps., 2 violet blended, 2 red separated. *p*-comp. displaced 0.062 to violet from normal. All comps. measured from normal
				normal	.....	.....	.....	
				0.264 (1)	.....	0.969	.....	
				0.400 (1)	.....	1.468	.....	
5222.849	3	Unaffected						
5223.791	3	Triple	2	0.437	.....	1.887	.....	
5224.471	8	Triple	3	0.631	.....	2.312	.....	
5224.712	5	Triple	2	0.608	.....	2.227	.....	
5225.198	6	Triple	2	0.548	.....	2.007	.....	
5226.707	10	Triple	3	0.349	.....	1.277	.....	Enhanced line
5238.742	3	Triple?	2	0.379 w_1	w_1	1.381	.....	
5247.466	2	Sextuple?	1	0.773 w_2	w_2	2.808	.....	
5252.276	3	Sextuple?	2	0.686 w_2	w_2	2.487	.....	
5255.973	3	Triple?	2	0.647 w_1	w_1	2.342	.....	
5260.142	1	Triple	2	0.430	.....	1.554	.....	
5262.321	1	Sextuple?	2	0.739 w_2	w_2	2.671	.....	Enhanced line

TABLE 2.—MEASUREMENTS OF ZEEMAN EFFECT FOR TITANIUM—Continued.

λ	INTENSITY.	CHARACTER OF SEPARATION.	WEIGHT.	Δλ		Δλ/λ²		REMARKS.
				n-COMP.	*p*-COMP.	*n*-COMP.	*p*-COMP.	
5263.669	1	Triple?	2	0.701 w_1	.....	2.530	.....	
5266.141	6	Triple	3	0.498	.....	1.796	.....	
5282.576	2	Sextuple?		n.m. w_2	w_2	.....	.....	
5283.613	6	Triple	3	0.469	.....	1.680	.....	
5284.281	1	Triple		n.m.	.....	.....	.....	
5295.955	3	Triple?	2	0.562 w_1	w_1	2.004	.....	
5297.407	5	Triple	3	0.389	.....	1.386	.....	
5298.672	4	Triple	3	0.475	....	1.692	.....	
5336.974	10	Triple	3	0.495	.....	1.738	.....	Enhanced line
5351.261	4	Triple?	2	0.487 w_1	w_1	1.701	.....	
5369.782	5	Triple	3	0.480	.....	1.665	.....	
5381.221	7	Triple	3	0.440	.....	1.520	.....	Enhanced line
5390.203	3	Triple	1	0.422	.....	1.452	.....	
5397.271	4	Triple	2	0.488	.....	1.675	.....	λ by Fiebig
5404.216	2	Triple?	1	0.735 w_1	w_1	2.517	.....	λ by Fiebig
5409.823	7	Triple	3	0.501	.....	1.712	.....	
5418.979	3	10 comps.	1,2	0.538 w_2	0.346 w_2	1.832	1.178	Probably 6 *n*-, 4 *p*-comps. Enhanced line
5429.349	4	Triple	3	0.753	.....	2.555	.....	
5474.436	4	Triple	1	0.512	.....	1.709	.....	Blend makes measurement difficult
5477.901	6	Triple	2	0.620	.....	2.066	.....	
5481.652	4	Triple	2	0.549	.....	1.827	.....	
5482.078	4	?		n.m.	n.m.	.....	.....	Numerous *n*- and *p*-comps. blurred
5488.374	2	Triple?	1	0.338 w_1	w_1	1.122	.....	
5490.367	7	Sextuple?	2	0.390 w_2	w_2	1.294	.....	*n*-comps. fringed
5504.117	8	Triple	3	0.515	.....	1.700	.....	
5512.741	12	Triple	3	0.567	.....	1.869	.....	
5514.563	12	Triple	3	0.363	.....	1.193	.....	
5514.753	12	Triple	3	0.466	.....	1.532	.....	
5565.700	8	Sextuple?	2,2	0.475 w_2	0.287	1.533	0.926	
5644.365	12	Triple	3	0.508	.....	1.595	.....	
5648.796	4	Triple?	2	0.575	w_1	1.802	.....	
5662.374	10	Sextuple?	2	0.676 w_1	w_1	2.109	.....	
5663.155	3	Triple	2	0.462	.....	1.441	.....	
5675.647	8	Sextuple?	2	0.564 w_1	w_1	1.751	.....	
5689.694	6	Sextuple?	2	0.515 w_2	w_2	1.591	.. ..	
5702.876	4	?	1	0.361 w_2	w_2	1.110	.....	*n*-comps. fringed and diffuse
5708.435	2	Sextuple?	2,1	0.846 w_2	0.373	2.596	1.145	λ by Fiebig
5712.098	3	Sextuple?	2,1	0.790 w_2	0.360	2.421	1.103	
5714.120	2	Unaffected						
5715.308	6	Triple	3	0.623	.....	1.907	.....	
5716.671	3	Sextuple?	2,2	0.673 w_2	0.502	2.059	1.536	
5720.666	3	Quintuple	1,2	0.473 (1)	0.882	1.445	2.695	Difficult
				0.000 (2)	.....	0.000	.....	
				0.476 (1)	.....	1.454	.....	
5739.698	5	Triple	3	0.555	.....	1.684	.....	
5740.195	3	Triple	2	0.508	.....	1.542	.....	
5762.479	1	Sextuple?		n.m. w_2	w_2	.....	.....	*n*-comps. diffuse, barely separated
5766.550	1	Triple	2	0.535	.....	1.609	.....	
5774.250	2	Triple	2	0.569	.....	1.707	.....	
5781.130	1	Sextuple?		n.m. w_2	w_2	.....	.....	
5786.193	2	Triple	2	0.635	. ....	1.897	.....	
5804.479	2	Triple?	2	0.634 w_1	w_1	1.882	.....	
5823.910	2	Sextuple?	2,2	0.480 w_2	0.268	1.415	0.790	
5866.675	10	Triple	3	0.674	.....	1.958	.....	
5880.490	3	Triple	3	0.830	.....	2.401	.....	
5899.518	7	Triple	3	0.656	.....	1.885	.....	
5903.555	2	Triple	2	0.876	.....	2.513	.....	Red comp. strongest?
5918.773	3	Triple	3	0.882	.....	2.518	.....	
5922.334	5	Triple	2	0.312	.....	0.890	.....	
5938.035	2	Sextuple?	2,1	0.840 w_2	0.226	2.382	0.641	*p*-comp. scarcely resolved
5941.985	5	Sextuple	2,2	Pair II, 0.905 (2)	0.547	2.563	1.549	
				Pair I, 0.295 (3)	.....	0.836	.....	
5953.386	8	Triple	3	0.637	.....	1.798	.....	

Table 2.—Measurements of Zeeman Effect for Titanium—Continued.

λ	Intensity.	Character of separation.	Weight.	$\Delta\lambda$		$\Delta\lambda/\lambda^2$		Remarks.
				n-comp.	*p*-comp.	*n*-comp.	*p*-comp.	
5966.055	7	Triple	3	0.590	.....	1.617	.....	
5978.768	7	Triple	3	0.533	.....	1.491	.....	
5999.920	2	Quadruple?	2	0.823 w_1	w_2	2.286	.....	
6064.853	2	Triple	3	1.159	.....	3.151	.....	
6085.470	4	Sextuple?	2,2	1.001 w_2	0.307	2.703	0.829	
6091.395	6	Triple	3	0.679	.....	1.830	.....	
6093.030	1	Triple	2	0.755	.....	2.034	.....	
6098.870	2	Triple?	2	0.563 w_1	w_1	1.514	.....	
6121.215	1	Triple	2	0.622	.....	1.660	.....	
6126.435	5	Septuple?	2	0.706 w_1	w_3	1.881	.....	*n*-comps. fringed. Probably 3 *p*-comps.
6146.445	1	Triple	2	0.476	.....	1.260	.....	
6149.950	1	Triple	2	0.698	.....	1.845	.....	
6215.630	3	Triple	3	0.697	.....	1.804	.....	
6220.700	2	Triple	2	0.618	.....	1.597	.....	
6221.552	1	Triple	2	0.511	.....	1.320	.....	
6258.322	10	Triple	2	0.661	.....	1.688	.....	Red *n*-comp. of first line blended with violet comp. of second
6258.927	12	Triple	2	0.714	.....	1.823		
6261.316	10	Triple	3	0.556	.....	1.418	.....	
6303.985	5	Octuple?	2,2	0.565 w_3	0.554	1.422	1.394	*n*-comps. very wide and diffuse. Probably at least 3 pairs
6312.456	5	Octuple?	2,2	0.766 w_3	0.463 w_1	1.923	1.162	*n*-comps. wide, not so diffuse as 6304. Probably 3 pairs. Possibly 4 *p*-comps.
6318.239	2	Triple	2	0.529	.....	1.335	.....	
6336.329	4	Triple	2	0.606	.....	1.510	.....	
6366.564	4	Triple?	2	0.671 w_1	w_1	1.655	.....	
6419.329	1	Sextuple?	1	0.758 w_2	w_1	1.840	.....	λ by Fiebig
6491.800	5	Triple	2	0.752	.....	1.785	.....	Enhanced line *Ti*? Not given by Fiebig for arc
6497.840	2	Triple	2	1.209	.....	2.863	.....	Titanium?
6508.380	2	?	1	1.318 w_3	w_3	3.112	.....	*n*-comps. very wide and diffuse
6513.300	2	Triple	2	0.610	.....	1.438	.....	Enhanced line *Ti*? Not given by Fiebig for arc
6546.479	8	Triple	2	0.459	.....	1.071	.....	
6554.470	9	Triple	3	0.795	.....	1.851	.....	
6556.308	10	Triple	3	0.896	.....	2.085	.....	
6559.815	3	Triple	2	0.594	.....	1.380	.....	*Ti*? Not given by Fiebig
6565.783	2	Sextuple?	1	1.000 w_2	w_2	2.320	.....	*Ti*? Not given by Fiebig
6575.437	2	Triple?	1	0.644 w_1	.....	1.489	.....	λ by Fiebig
6599.353	5	Triple	3	0.711	.....	1.633	.....	
6606.160	2	Quadruple?	2	0.881 w_1	w_1	2.019	.....	*Ti*? Not given by Fiebig
6666.714	2	Triple?	1	0.753 w_1	w_1	1.694	.....	λ by Fiebig. Blended with fluting lines
6667.998	2	Triple?		n.m. w_1	w_1	.....		
6716.922	2	Triple	1	0.772	.....	1.711		
6717.964	2	Triple	1	0.862	.....	1.910		
6743.381	6	Triple	2	0.759	.....	1.669	.....	

TYPES OF SEPARATION.

The number of lines for each type of separation, including both the clear and the doubtful cases, is given in Table 3. For the quadruplets, sextuplets, and septuplets, the questioned lines greatly outnumber the clear cases. For example, iron shows only two clear septuplets and titanium two clear quadruplets. A strong field will probably show that these doubtful lines have usually been correctly classified as to number of components, but actual measurements for the unresolved components are at present lacking.

Table 3.—Summary of Types of Separation.

Separation.	Iron.	Titanium.
Unaffected	9	4
Triple	393	291
Quadruple	49	28
Quintuple	7	5
Sextuple	118	77
Septuple	37	12
Octuple	6	11
9 components	9	3
10 components	7	7
11 components	2	2
12 components	4	2
13 components	2	0
Unclassified	19	16
Total	662	458

1. Unaffected Lines.

A number of lines in each spectrum show no tendency toward separation or even widening by a magnetic field as high as 20,000 gausses. The light giving such lines is unpolarized so that a single sharp line appears in the magnetic field spectrum, whatever the optical system may be. The number of these lines is not large, the undoubted cases being as herewith:

Iron.		Titanium.
λ3746.058	λ3850.118	λ4295.914
3767.341	5123.899	5222.849
3773.803	5434.740	5714.120
3786.820	5576.320	......

2. Triplets.

The number of triplets is larger than that of any other one type, the number of clear cases, i.e., those whose components show no widening which would indicate that they are compound, being 297 for iron and 247 for titanium. The relation of the separation of these to the "normal interval" will be treated in another part of this paper.

A rather curious mistake has found its way into the literature based on some lines in the iron spectrum. Becquerel and Deslandres in their first publication (9) gave λ3865.674 as an "inverted triplet," having but a single *n*-component and two *p*-components. This evidently arose from under-exposure of their photographs for the *n*-component, as in their next paper (10) they gave the correct character of this line, it being a quintuplet with three *n*- and two *p*-components, the central *n*-component being strongest. Reese (12) made the same error concerning both this line and λ 3643.469, together with another farther to the violet. Kent (13) followed with a publication in which the lines are correctly described. Cotton (1a) calls attention to the confusion which has come about and gives the correct structure. Runge (2b) cites the first paper of Becquerel and Deslandres and that of Reese concerning the inverted triplet, without noting that the error had been corrected in each case by later publications, though Runge later (2c) reproduced the diagram of Becquerel and Deslandres from their second paper, in which the correct structure of these lines is given. Other works on spectroscopy speak of the inverted triplet, the basis for this being the publications which have been mentioned. No real case of the inverted triplet has presented itself in the iron or titanium spectrum, nor, so far as the author is aware, does such a type exist in any other spectrum. Apparent examples of such inversion are likely to appear on plates not fully exposed, since some quintuplets, λ4464.617 of titanium for example, show a central *n*-component very much stronger than the two outer ones, so that the central component may easily appear alone.

The tendency of Zeeman components to follow the appearance of the no-field line as regards sharpness or diffuseness frequently makes it difficult to judge whether a line is a true triplet or not. If the lack of sharpness is not due to the character of the no-field line, a doubtful triplet may be (1) a quadruplet if the diffuse *p*-component is really double, (2) a sextuplet if each of the three widened *n*- and *p*-components are double, (3) a septuplet if the two *n*-components are double and the *p*-component has three close constituents. Still higher separations for doubtful triplets are not impossible, but probably there are very few such. The criterion for distinguishing between these possible types is given on p. 19.

3. Quadruplets.

The unquestioned quadruplet is somewhat rare. The great majority of lines having two *n*- and two *p*-components have their *n*-components widened to some extent and are usually classed as doubtful sextuplets, since so many of these have been resolved by the strongest fields used that it seems probable that a still stronger field would show four *n*-components for such lines in every case. Occasionally, however, the two *n*-components are sharp. The relative separation of *n*- and *p*-components varies greatly for different lines, but the *p*-components are almost always closer together. The most decided exception is the titanium line λ4398.460, apparently a quadruplet, whose *n*-components show only two-thirds the separation of the *p* pair.

4. Quintuplets.

The quintuplet appears least often of any of the less complex types. As a rule this separation gives three *n*- and two *p*-components, the distance between the *p*-components being the same as between the outer *n*-components. The central *n*-component is the strongest of the three, and the effect when the light is observed at right angles to the lines of force without a Nicol prism is to give a triplet, the components of which are of about equal intensity, caused by the superposition of the *p* doublet on the two outer *n*-components. Good examples are λλ3733.469 and 3865.674 of iron, and 4291.114 of titanium. The first two were originally mistaken for "inverted triplets" on account of the strong central *n*-component. Dissymmetry is sometimes present, as in λ 5455.834 of iron. A different type is presented in λ 4710.368 of titanium, which shows four *n*-components and a single sharp *p*-component. No similar line has been observed in either of these spectra.

5. Sextuplets.

This type usually has the two pairs of *n*-components of equal intensity, shown by a uniform widening in cases where the pairs are blended. As has been previously noted, the sextuplet is a very common type, a great number of lines being classed as probable sextuplets which show as diffuse triplets with this field. A field of considerably greater intensity will probably show these to be similar to most of the sextuplets which are fully resolved here. The *p*-components of those sextuplets which have been measured are usually rather narrowly separated, while the two pairs of *n*-components are frequently almost blended.

6. Septuplets.

The prevailing type of septuplet has four *n*- and three *p*-components, the two pairs of *n*-components not usually being of the same intensity. When blended, the *n*-components give the "fringed" appearance often noted in the "Remarks" column, in which case the weaker pair may be either inside or outside. When the *p*-components are not resolved, it is often difficult to distinguish this type from the sextuplet, the difference depending on the existence of a central maximum in the widened *p*-component.

7. Octuplets.

The typical octuplet has five *n*- and three *p*-components, equally spaced. The outer *n*-components are usually the stronger and the central one quite weak, so that when the three *p*-components, if the central one is the stronger, are superposed, as when the light is viewed across the lines of force without a Nicol, the effect is to show five components of about equal intensity. Examples of such lines are λλ 3743.508, 3788.046, 5497.735, of iron, and 4281.530, 4527.490, 4544.864, of titanium. The last two were given as septuplets in my former paper (51) on account of the weakness of the central *n*-component. Another arrangement is presented by the titanium line λ 4308.081 which has three pairs of *n*-components and two *p*-components.

8. Nonets.

Good examples of lines having nine components are found in λλ 3840.580, 4233.772 of iron, and 4471.408 4489.262, 4629.521 of titanium. These have each three pairs of *n*-components, the innermost pair being strongest, and three *p*-components. The type is probably rather common in both spectra, since many lines classed as doubtful septuplets may have a weak outer pair of *n*-components, making a total of nine.

9. More Complex Types.

Lines having ten components are represented by λλ 4417.884, 4471.017, and 5025.027 of titanium. These are made up in each case of three pairs of *n*- and two pairs of *p*-components. Eleven components are shown by λ 3888.671 of iron, which has a central *n*-component in addition to the pairs of the ten-component type. Several good examples of twelve-component lines are given by λλ 3722.729, 3872.639, 5447.130 of iron and 4289.237 of titanium. These are all of similar structure, having four pairs of *n*-components, the two inner pairs having the same separation as the two pairs of *p*-components. While twelve is the highest number of components which is measurable on my plates, the iron lines λλ 4005.408 and 4132.235 are given as probably having thirteen components each. Five *p*-components are almost resolved in each case and the wide inner fringes for the *n*-components are estimated to consist of four pairs. Many of the lines whose type is questioned without attempt to estimate the number of components have probably as many as the most complex of those measured, and some of them possibly more.

Good examples of almost all of these types of separation are present among the violet iron lines shown in Plate III, which has the advantage of showing the *n*- and *p*-components both separate and in combination, the latter spectrum being taken at right angles to the force-lines without the use of a Nicol prism. Polarization by the grating reduced the intensity of the *p*-component for this region of the spectrum, as is shown by the relative weakness of the central component of triplets in the spectra lettered *b*, for which the Nicol prism was not used.

RELATION OF SEPARATIONS TO THE NORMAL INTERVAL.

1. Summaries for Various Types.

The study of how generally the separations observed show a simple relation to the fundamental interval, the theory of which was summarized on p. 4, has been gone into in some detail. The relation

$$a=\frac{e}{m}\cdot\frac{H}{4\pi v}$$

gives a value for *a* of 0.753 for $H=16,000$, and of 0.812 for $H=17,500$, if e/m be taken equal to 1.75×10^7. The "normal triplets" for iron and titanium, with the standard field-strengths used in this work, should accordingly show values of $\Delta\lambda/\lambda^2$ for the distance between the side components of about 1.500 and 1.600 respectively.

In the following summaries an attempt has been made to show to what extent the separations for various classes of lines may be considered as multiples of the interval *a*. In Table 4 the clear triplets for iron and titanium are thus classified, those triplets given in Tables 1 and 2 as doubtful not being included. The allowable deviation for any line from the exact multiple was estimated as closely as possible according to the weight of the measurement, knowing the probable error for each weight. Lines not falling into any class are placed in the "Odd" column. In the case of titanium a large proportion of such lines appeared to be definite odd multiples of $a/4$, while the regular classes consider only multiples of $a/2$. As in all of the following work relating to the interval *a*, greater field strength is desirable, as the accuracy of the classification increases with the numerical value of *a;* but Table 4 shows in a general way how the magnitudes of the separations may be grouped.

Table 4.—Separation of Triplets as Related to the Normal Interval *a*.

	a	$3a/2$	$2a$	$5a/2$	$3a$	$7a/2$	$4a$	$5a$	$6a$	Odd	Remarks.
Element, Iron:											
Wt. 3.........	0	5	25	17	35	6	4	3	4	16	
Wt. 2.........	2	11	19	27	27	2	2	0	0	20	
Wt. 1.........	1	5	10	11	10	3	1	0	0	6	
Total	3	21	54	55	72	11	7	3	4	42	
Element, Titanium:											
Wt. 3.........	0	5	40	15	14	1	1	2	0	76	"Odd" includes $7a/4$, 14 lines; $9a/4$, 32 lines
Wt. 2.........	5	5	27	13	2	2	1	0	0	21	"Odd" includes $7a/4$, 7 lines; $9a/4$, 8 lines
Wt. 1.........	2	1	6	2	1	0	0	0	0	0	
Total	7	11	73	30	17	3	2	2	0	97	

The relation of the separation to the normal interval was also studied for those lines which appear on my plates as quadruplets with components in many cases diffuse, indicating a compound structure. The two *p*-components are usually fairly sharp, but the *n*-components are often formed of two or more pairs blended. Close agreement with exact multiples of the normal interval can not be expected for lines of this class, but in the majority of cases the distance between the components of the *n* and *p* pairs could be expressed as multiples of *a* or $a/2$ closely enough to show a real relation; 66 lines of iron and

49 of titanium were thus treated, and 80 per cent of the former and 75 per cent of the latter were found to show separations related to *a* in this way. Table 5 gives the number of lines corresponding to each ratio of separation for *n*- and *p*-components when these could be expressed in terms of *a* or *a*/2.

TABLE 5.—SEPARATIONS OF APPARENT QUADRUPLETS IN TERMS OF NORMAL INTERVAL.

SEPARATION.		RATIO.	NO. OF LINES.		SEPARATION.		RATIO.	NO. OF LINES.	
n-COMP.	*p*-COMP.		IRON.	TITANIUM.	*n*-COMP.	*p*-COMP.		IRON.	TITANIUM.
2*a*	2*a*	1:1	2	3	5*a*/2	*a*	5:2	3	..
5*a*/2	5*a*/2	1:1	1	..	7*a*/2	*a*	7:2	..	1
2*a*	*a*	2:1	8	7	*a*	3*a*/2	2:3	..	1
6*a*	3*a*	2:1	2	..	2*a*	3*a*/2	4:3	..	3
3*a*	3*a*/2	2:1	4	2	5*a*/2	3*a*/2	5:3	..	1
3*a*	*a*	3:1	18	6	7*a*/2	3*a*/2	7:3	..	1
9*a*/2	3*a*/2	3:1	1	..	5*a*/2	2*a*	5:4	..	1
5*a*	*a*	5:1	1	..	n.m.	3*a*/2	...	1	3
3*a*	2*a*	3:2	5	1	n.m.	2*a*	...	4	6
3*a*/2	*a*	3:2	1	..	n.m.	3*a*	...	1	..

Fourteen lines of iron and 13 of titanium gave separations not to be expressed in terms of *a*/2, but most of these showed a simple ratio between the *n* and *p* separations. For iron, 2 lines showed a ratio of 1:1, 6 lines of 2:1, 2 lines of 3:1, 2 lines of 4:1. The odd lines of titanium had among them 5 of ratio 2:1, and 1 of ratio 4:1.

The more complex lines, so far as they were resolved by the field employed, have been arranged in the following summary. In each case, below the wave-length, the first column gives the interval in terms of *a* from either the red or the violet component to the center of separation. (The triplets and quadruplets in Tables 4 and 5 have their separations given as the total distance from the red to the violet component.) The second column shows whether it is the *n*- or *p*-component which has this separation. If both letters are present for a given interval, there is a superposition of components having the two polarizations. The last column gives the ratio of the successive intervals.

QUINTUPLETS.

Iron:	λ 3718.554
	$\pm 5a/4$ *n* 2
	$5a/8$ *p* 1
	0 *n* 0

$$\left\{\begin{array}{ll}\lambda\lambda\ 3733.469 & 3865.674\\ 3760.679 & 5455.834\\ 3814.671 & 5603.186\end{array}\right\}\text{ have the arrangement }\left\{\begin{array}{lll}\pm 3a/2 & n,p & -\\ 0 & n & -\end{array}\right.$$

Titanium:	λ 4291.114	λ 4464.617	λ 4710.368	λ 5720.666
	$\pm 3a/2$ *n,p* —	$\pm 7a/4$ *n* 2	$\pm 4a/3$ *n* 8	$\pm 3a/2$ *n,p* —
	0 *n* —	$7a/8$ *p* 1	$a/2$ *n* 3	0 *n* —
		0 *n* 0	0 *p* 0	

SEXTUPLETS.

Iron:	λ 3774.971	λ 4109.953	λ 4422.741	λ 4447.892	λ 4872.332	λ 6213.644	λ 6337.048
	$\pm 5a/2$ *n* 10	$\pm 3a/2$ *n* 2	$\pm 3a/2$ *n* 3	$\pm 2a$ *n* 4	$\pm 3a$ *n* 2	$\pm 3a$ *n* 6	$\pm 3a$ *n* 6
	$5a/4$ *n* 5	$3a/4$ *n,p* 1	a *p* 2	$3a/2$ *n* 3	$3a/2$ *n,p* 1	$3a/2$ *n* 3	$3a/2$ *n* 3
	a *p* 4	......	$a/2$ *n* 1	a *p* 2	......	a *p* 2	a *p* 2

Titanium:	λ 3982.142	λ 4302.085	λ 4321.119	λ 4640.119	λ 4722.797	λ 4798.169	λ 4805.285	λ 5941.985
	$\pm 3a/2$ *n* 3	$\pm 2a$ *n* 8	$\pm 21a/8$ *n* 3	$\pm 5a/2$ *n* 5	$\pm 3a/2$ *n* 12	$\pm 3a/2$ *n* 3	$\pm 3a/2$ *n* 3	$\pm 3a/2$ *n* 3
	a *p* 2	$3a/4$ *p* 3	$7a/8$ *n,p* 1	$3a/2$ *n* 3	$9a/8$ *p* 9	a *p* 2	a *n* 2	a *p* 2
	$a/2$ *n* 1	$a/2$ *n* 2	......	a *p* 1	$5a/8$ *n* 5	$a/2$ *n* 1	$a/2$ *p* 1	$a/2$ *n* 1

SEPTUPLETS.

Iron:	λ 4009.864	λ 4191.595	λ 4352.908	λ 5079.921
	$\pm 2a$ *n* 8	$\pm 2a$ *n* 2	$\pm(2a$ *n* 4)?	$\pm 2a$ *n* 2
	a *n* 4	a *n,p* 1	$3a/2$ *n* 3	a *n*?,*p* 1
	$3a/4$ *p* 3	0 *p* 0	$a/2$ *p* 1	0 *p* 0
	0 *p* 0	......	0 *p* 0	......

Titanium:	λ 4298.828
	$\pm a$ *n* 2
	$a/2$ *n,p* 1
	0 *p* 0

OCTUPLETS.

Iron:	λ 3743.508	λ 3788.046	λ 4859.928	λ 5497.735
	±2*a* *n* 2	±2*a* *n* 2	±(3*a* *n* 2)?	±3*a* *n* 2
	a *n*,*p* 1	*a* *n*,*p* 1	3*a*/2 *n*,*p* 1	3*a*/2 *n*,*p* 1
	0 *n*,*p* 0	0 *n*,*p* 0	0 *n*,*p* 0	0 *n*,*p* 0

Titanium:	λ 4281.530	λ 4308.081	λ 4527.490	λ 4544.864	λ 4590.126
	±3*a* *n* 2	±2*a* *n* 8	±2*a* *n* 2	±2*a* *n* 2	±3*a*/2 *n* 12
	3*a*/2 *n*,*p* 1	3*a*/2 *n* 6	*a* *n*,*p* 1	*a* *n*,*p* 1	*a* *n* 8
	0 *n*,*p* 0	*a* *n* 4	0 *n*,*p* 0	0 *n*,*p* 0	7*a*/8 *p* 7
	......	3*a*/4 *p* 3	......	......	*a*/2 *n* 4

NONETS.

Iron:	λ 3748.408	λ 3840.580	λ 4233.772	λ 5405.989
	±3*a*/2 *n* 3	±3*a*/2 *n* 3	±3*a* *n* 3	±(3*a*/2 *n* 3)?
	a *n* 2	*a* *n* 2	2*a* *n* 2	*a* *n* 2
	a/2 *n*,*p*?1	*a*/2 *n*,*p* 1	*a* *n*,*p* 1	*a*/2 *n*,*p* 1
	0 *p* 0	0 *p* 0	0 *p* 0	0 *p* 0

Titanium:	λ 4471.408	λ 4489.262	λ 4629.521
	±21*a*/8 *n* 7	±21*a*/8 *n* 7	±5*a*/2 *n* 5
	15*a*/8 *n* 5	15*a*/8 *n* 5	3*a*/2 *n* 3
	9*a*/8 *n* 3	9*a*/8 *n* 3	*a* *p* 2
	3*a*/4 *p* 2	3*a*/4 *p* 2	*a*/2 *n* 1
	0 *p* 0	0 *p* 0	0 *p* 0

TEN-COMPONENT LINES.

Titanium:	λ 4417.884	λ 4471.017	λ 5025.027
	± ? *n* ?	±9*a*/4 *n* 6	±3*a*/2 *n* 24(5)
	a *n* 8	3*a* /4*p* 4	5*a*/4 *p* 20(4)
	3*a*/4 *p* 6	9*a*/8 *n*,*p*? 3	*a* *n* 16(3)
	3*a*/8 *n* 3	3*a*/8 *n* 1	5*a*/8 *p* 10(2)
	a/4 *p* 2		5*a*/16 *n* 5(1)

The numbers in parentheses for λ5025.027 give a simpler relation between the intervals than the exact ratio of the multiples of parts of *a*. Another probable ten-component line is λ3982.630, for which the measurements are poor. Its *n*-components are in the ratio 5:3:1.

ELEVEN-COMPONENT LINES.

Iron:	λ 3888.671	λ 4871.512	Titanium:	λ 3930.022
	±3*a*/2 *n* 3	±(3*a*/2 *n* 3)?		±9*a*/4 *n*,*p* 3
	a *n*,*p* 2	*a* *n*,*p* 2		3*a*/2 *n*,*p*? 2
	a/2 *n*,*p*? 1	*a*/2 *n*?,*p* 1		3*a*/4 *n* 1
	0 *n* 0	0 *p* 0		0 *n* 0

λ4871.512 has its *n*-components blended, but the structure indicates the above arrangement.

The titanium line λ3921.563 has probably the same structure as λ3930.022. The *n*-components have the ratio 3:2:1:0, but the measurements are not good enough to be sure of the relation to *a*.

TWELVE-COMPONENT LINES.

Iron:	λ 3722.729	λ 3872.639	λ 5447.130	Titanium:	λ 4289.237
	±2*a* *n* 4	±2*a* *n* 4	±2*a* *n* 4		±2*a* *n* 4
	3*a*/2 *n* 3	3*a*/2 *n* 3	3*a*/2 *n* 3		3*a*/2 *n* 3
	a *n*,*p* 2	*a* *n*,*p* 2	*a* *n*,*p* 2		*a* *n*,*p* 2
	a/2 *n*,*p*?1	*a*/2 *n*,*p*?1	*a*/2 *n*,*p* 1		*a*/2 *n*,*p* 1

2. DISCUSSION OF RELATIONS TO NORMAL INTERVAL.

It is shown in Table 4 that for iron two-thirds and for titanium over one-half of the clear triplets are separated by the intervals 2*a*, 5*a*/2 and 3*a*. For both elements, however, a very large majority have separations of this order of magnitude, since almost all of the lines classified as "odd" give intervals within this range, the numbers corresponding to 7*a*/4 and 9*a*/4 of weights 1 and 2 being given for titanium in the "Remarks" column. A more precise classification, in which smaller fractional parts of *a* can be used, must await an investigation with greater field-strength, which will also decide the structure of most of the doubtful triplets, the separation of which is not included in any of these summaries.

Table 5 shows how generally the separations of those lines showing two *n*- and two *p*-components can be expressed in terms of the interval *a*, also the wide variety of separations which prevails. The ratios of 2:1 and 3:1 predominate for both elements. As has been previously noted, the *p*-components almost always show the narrower separation.

The ease with which the separations of the complex lines both in iron and titanium can be expressed in terms of a affords a confirmation of Runge's law, since failure to give approximation to exact multiples of a appears to occur only in the case of measurements of small weight. It has been necessary only in a very few cases to use multiples of any quantity smaller than $a/4$, so that errors of measurement are seldom large enough to influence the ratios found. This question will become of more importance when very close components are resolved by a stronger field.

The presence of "magnetic duplicates," lines exactly similar in structure, with the same intervals between components, furnishes a means of selecting lines which may be connected by series relations. Such duplicates occur for almost every type of separation. Six quintuplets of iron and two of titanium show the same structure and intervals. These are λλ3733.469, 3760.679, 3814.671, 3865.674, 5455.834, 5603.186 of iron and 4291.114, 5720.666 of titanium. Several types of sextuplets appear. The red lines of iron λλ6213.644 and 6337.048 are duplicates, also the titanium lines λλ3982.142, 4798.169, and 5491.985. Duplicate septuplets of iron are λλ4191.585 and 5079.921. The only titanium septuplet fully resolved, λ4298.828, has the same structure. The four iron octuplets are of the same appearance but have different spacing, λλ3743.508 and 3788.046 being alike, as are probably also λλ4859.928 and 5497.735, though the former was not fully measurable. The blue octuplets of titanium λλ4527.490 and 4544.864 are also duplicates. The iron nine-component lines λλ3748.408 and 3840.580 are alike, and λ5405.989 has probably the same intervals. Another spacing is shown by the titanium duplicates λλ4471.408 and 4489.262. The lines of iron which probably have ten components are not fully resolved, while the three titanium lines show diverse arrangements. Perhaps the finest examples of spacing in multiples of a are the twelve-component lines λλ3722.729, 3872.639, 5447.130 of iron, which are exact duplicates, while λ4289.237 of titanium is in all respects similar.

POSSIBLE RELATIONS BETWEEN LINES AS INDICATED BY THE ZEEMAN EFFECT.

It is hoped that the measurements presented in this paper, especially the summary of complex separations given on pp. 48 and 49, may eventually aid in finding definite relations among the lines of these spectra. At present, nothing conclusive along this line is to be offered. Numerous cases of magnetic duplicates have been shown to exist in both spectra. Such lines, especially if they are in the same part of the spectrum, are often affected in the same way as to change of intensity in various light sources and show a similar magnitude of displacement by pressure. The same vibrating particle probably produces them.

The differences in wave-number (1/λ) have been formed for the various pairs of magnetic duplicates. Only one case was found where two pairs of magnetic duplicates have the same difference of wave-number. The iron octuplets λλ3743.508 and 3788.046 have exactly the same difference in wave-number (314) as the sextuplets λλ6313.644 and 6337.048. No case was found where two pairs of magnetic duplicates of the same type have the same difference, though this was tried wherever promising, both between known duplicates and as a means of finding new pairs. The differences between duplicates were found to vary greatly for each element and to bear no simple relation to one another; so that as yet no clue has been found which will serve in building up series relations.

CASES OF DISSYMMETRY.

There are but few striking examples of dissymmetry in the iron and titanium spectra, either in spacing of the components or in the intensities of the violet and red components. However, fourteen lines showing distinct dissymmetry may be listed as shown herewith:

The nature of the dissymmetry is covered in each case in the "Remarks" column. Several triplets show either the red or the violet component decidedly stronger. Quintuplets are likely to show irregular spacing or intensity, or both, as in the cases of λλ3718.554, 3760.679 and 5455.834, of iron. The last line has its central *n*-component moved distinctly to the red from the position of the no-field line (see Plate IV). The titanium septuplet λ4298.828 shows three *p*-components, the interval between the central and violet components being about two-thirds that between the central and red. This line appears on Plate V. Several of the other lines are of complex type and highly unsymmetrical.

Iron.	Titanium.
λ3718.554	λ3998.790
3760.679	4009.807
3892.069	4298.828
3952.754	4645.368
4878.407	4997.283
5324.373	5219.875
5455.834	5903.555

The plates taken in this investigation are for the most part not suitable for the detection of a difference in the spacing from the central line of the violet and red component of triplets, since a Nicol was almost always used to separate the *n*- and *p*-components. However, two of the best plates in the set were taken without a Nicol for the iron spectrum in the blue and violet regions and include most of the lines mentioned by Zeeman (30) as showing a difference in the intensity or in the spacing of the violet and red components. These plates were taken with a field-strength of 19,500 gausses. A set of measurements was made for the sharpest triplets occurring in this region to test the question of a difference in the spacing of the violet and red components from the central line. The method was to make settings successively on the violet, central, and red components, and then repeat in the inverse direction, continuing until four sets of readings were obtained from which the mean distance to each side component was computed. The measurements given in Table 6 are the mean of two independent sets taken in this way, which in general agreed closely. Thus each value of Δλ is the mean of eight determinations of the interval in question. The values of Δλ are not reduced to the standard field. Differences in favor of the violet interval are +, those in favor of the red interval −.

Table 6.—Spacing of Violet and Red Components of Iron Triplets from the Central Component.

λ	Δλ		Difference.	λ	Δλ		Difference.
	Center to Violet.	Center to Red.			Center to Violet.	Center to Red.	
3687.610	0.204	0.198	+0.006	3920.410	0.231	0.218	+0.013
3709.389	0.200	0.201	−0.001	3923.054	0.228	0.223	+0.005
3758.375	0.179	0.165	+0.014	3928.075	0.227	0.223	+0.004
3763.945	0.148	0.136	+0.012	3930.450	0.230	0.221	+0.009
3765.689	0.153	0.142	+0.011	3997.547	0.173	0.168	+0.005
3798.655	0.212	0.209	+0.003	4063.759	0.179	0.177	+0.002
3799.693	0.213	0.211	+0.002	4236.112	0.285	0.280	+0.005
3827.980	0.153	0.139	+0.014	4260.640	0.278	0.272	+0.006
3856.524	0.222	0.213	+0.009	4271.934	0.218	0.216	+0.002
3860.055	0.217	0.219	−0.002	4308.081	0.200	0.194	+0.006
3886.434	0.225	0.214	+0.011	4325.939	0.170	0.161	+0.009
3895.803	0.223	0.223	0.000	4383.720	0.217	0.210	+0.007
3899.850	0.225	0.221	+0.004	4404.927	0.212	0.208	+0.004

These measurements are intended only as a preliminary test of the reality of the difference in triplet spacings. The evidence, however, points strongly to the existence of a true difference for many, if not all triplets. Only 3 out of 26 lines fail to show a larger interval for the violet component. Although the settings on a component seldom show a range greater than 0.004 Å, which would indicate a very small probable error in the mean of 8 determinations, it is likely that the actual probable error of the individual differences shown in Table 6 may amount to 0.003 or 0.004 Å as a result of systematic errors in the settings due to the character of the lines. The mean of all the differences is + 0.006 Å, with a calculated probable error of ± 0.001 Å, which can scarcely leave any doubt as to the reality of the difference.

The measurements show that the magnitude of the difference can hardly be the same for all of the lines. The true probable error will then be somewhat smaller than that given above, which would only make the evidence for the reality of the dissymmetry predicted by Voigt the stronger. The lines from λ3930.450 toward the violet, 17 in number, are with one exception either normal triplets or have the separation $3a$, usually the latter. Of the 9 lines showing a difference greater than 0.008 Å, 3 are normal triplets and 4 have a separation of $3a$. The question of dissymmetry seems worthy of investigation through a long range of field-strengths for these lines, especially to test the generality of the change of spacing with the square of the field-strength observed for one of the lines in the mercury spectrum (see p. 5).

An element which might sometimes affect the spacing of Zeeman components is the apparent difference in the wave-lengths of arc and spark lines. The spark is made more disruptive by the magnetic field, and a greater disruptiveness seems in general to cause the lines of the spark to be moved slightly toward the red as compared with their positions in the arc spectrum. The reality of this effect is still a disputed question, but evidence published by a number of observers, as well as some photographs of the arc and spark which I have taken for this portion of the iron spectrum, indicate that measurements taken in the regular way will give a slightly greater wave-length for the spark lines, the difference being greatest for a very disruptive spark. If this effect has a part in the Zeeman phenomenon, we should expect all components of the triplet to be displaced alike. The greater strength of the middle component, however, would probably make the effect more perceptible for this, as the apparent displacement is more or less combined with unsymmetrical widening and is usually more distinct for strong lines. However, in the photographs from which the measurements of Table 6 were taken, triplets to the violet of λ4000 show the middle component only about as strong as either side component on account of the polarization given by the angle of the grating used, so that the conditions of the spark discharge would not seem to be adequate to explain the difference in spacing, unless the direction of vibration of the electrons, parallel or perpendicular to the lines of force, affects their susceptibility to the displacing action of the spark discharge. On this point we have no evidence.

The other point of dissymmetry predicted by Voigt, a greater strength for the red component of the triplet, is quite perceptible for many lines, especially in the iron spectrum. The difference is rarely greater than 10 per cent., and, to be clearly detected, the two components must be distinct but not of full density, since blackness of the components in the negative destroys so slight a difference. On account of this necessity for just the right degree of exposure, it is difficult to say how general the phenomenon is, but it is certainly present for many lines.

LAW OF CHANGE OF THE AVERAGE SEPARATION OF THE *N*-COMPONENTS WITH THE WAVE-LENGTH.

A glance through Tables 1 and 2 shows that for both iron and titanium the tendency is for the values of $\Delta\lambda$ gradually to increase as we pass to greater wave-lengths, while the values of $\Delta\lambda/\lambda^2$ remain of about the same magnitude throughout. A statistical study of this apparent constancy of the averages $\Delta\lambda/\lambda^2$ has been made; and both the range of wave-length and the number of lines available are sufficient to show clearly how the matter stands.

The method of treatment has been to obtain the mean value of $\Delta\lambda/\lambda^2$ for the *n*-components for each 500 Å from λ 3700 to λ 6700. When there are two or more pairs of *n*-components the mean of the separations is taken. This is necessary for the sake of consistency if any lines other than clear triplets or quadruplets are to be considered, since the measurement of the widened *n*-components given by a great many lines is merely the mean separation of two or more unresolved pairs.

The averages thus obtained are presented in Table 7. The means for the six groups of 500 Å are given first, then the means for the three groups of 1000 Å. These latter are the means for the whole number of lines considered in the range, not the averages of the means for the 500-groups. Of course, no account can be taken in this summary of the considerable number of lines which are described, but whose *n*-components are not measurable.

TABLE 7.—MEANS OF $\Delta\lambda/\lambda^2$ (*n*-COMPONENTS) FOR SUCCESSIVE REGIONS OF WAVE-LENGTH.

RANGE OF λ.	IRON.		TITANIUM.	
	NO. OF LINES.	MEAN $\Delta\lambda/\lambda^2$.	NO. OF LINES.	MEAN $\Delta\lambda/\lambda^2$.
3700–4200	267	2.003	80	1.909
4200–4700	101	2.051	152	2.027
4700–5200	74	2.125	81	1.684
5200–5700	62	1.932	47	1.819
5700–6200	37	1.837	34	1.942
6200–6700	41	2.131	28	1.764
3700–4700	368	2.016	232	1.986
4700–5700	136	2.037	128	1.734
5700–6700	78	1.989	62	1.862

The close agreement of the means shows that there is a real relation, giving an approximate constancy of the values of $\Delta\lambda/\lambda^2$ for different parts of the spectrum. Taking the successive means of the 500-groups, the average value for iron is 2.013, for titanium 1.858. The largest deviation from the mean for any group is 8.7 per cent for iron and 9.4 per cent for titanium. For neither element is there any systematic change in the means for successive groups.

The means for the groups of 1000 Å show a still closer agreement, the largest deviation from the mean of these groups being only 1.2 per cent for iron and 6.8 per cent for titanium.

It will be noticed that the mean values for titanium run smaller than those for iron, although the titanium measurements correspond to the larger field-strength. A number of spectra will have to be examined in this way and the measurements reduced to the same field-strength before we can say what significance, if any, there is in this point. It may prove to be connected with certain properties of the elements concerned.

It is not difficult to see that this constancy of the mean value of $\Delta\lambda/\lambda^2$ depends on the general relation of this quotient to the fundamental interval a, and that it results from the fact that the great majority of the separations for the *n*-components range from the values of $2a$ to $3a$ and that the various values of the multiples of the interval are more or less uniformly distributed throughout the spectrum. This was shown for the triplets (p. 47), the greater number of which show a separation greater than $2a$. The exceptional large and small values for triplets, together with the mean separations of the complex lines, combine to form a fairly definite mean which holds for the whole range of spectrum examined.

Since $\Delta\lambda/\lambda^2$ is shown to be very nearly constant, it may be said that for the spectra of iron and titanium, and probably for spectra in general, the mean separation of the n-components varies as the square of the wave-length.

A similar rule must hold for the *p*-components, since it was shown (pp. 48-49) that complex lines of the same structure in different parts of the spectrum show the same relation to the interval *a*.

It is of interest to note that a computation along the lines of that carried out here, but different in method and with comparatively little material at disposal, was made by Mr. Hale (38) in his comparison of sun-spot doublets with the Zeeman separations on some preliminary plates made by the author. The mean $\Delta\lambda$ for a number of iron lines in the blue was divided by the square of the mean wave-length for the region considered. Measurements for lines extending from the green into the red were treated similarly. The quotients of the mean $\Delta\lambda$ by the square of the mean λ for the two regions agreed exactly. While this result does not have the same significance as the comparison of the mean values of $\Delta\lambda/\lambda^2$, it is clearly based on the same relation for the rate of increase of $\Delta\lambda$ with λ.

THE EFFECT OF THE MAGNETIC FIELD UPON ENHANCED LINES.

In my former paper (51) on the titanium spectrum, the behavior of the enhanced lines was examined to see if, as a class, they were affected by the magnetic field differently from the non-enhanced lines. The various types of separation were found to occur in about the same proportion for the enhanced lines as for the spectrum in general. The same conclusion was arrived at by Mr. Babcock (62) for the enhanced lines of chromium and of vanadium.

Table 8 gives the numbers of enhanced and non-enhanced lines considered both as to type and magnitude of separation. Here, as in Table 3, a given type includes both the clear and the questioned cases for that type occurring in Tables 1 and 2.

TABLE 8.—COMPARISON OF TYPES OF SEPARATION FOR ENHANCED AND NON-ENHANCED LINES.

CHARACTER OF SEPARATION.	IRON.		TITANIUM.	
	ENHANCED.	NON-ENHANCED.	ENHANCED.	NON-ENHANCED.
Unaffected.......	0	9	0	4
Triple...........	25	368	49	242
Quadruple.......	4	45	5	23
Quintuple........	0	7	1	4
Sextuple..... ...	8	110	13	64
Septuple.........	3	34	1	11
Complex.........	3	46	13	28
Total.........	43	619	82	376

The enhanced lines of each element are found to present a diversity of types. The enhanced and non-enhanced triplets are in about the same ratio as the total number of enhanced and non-enhanced lines, both for iron and titanium, this ratio being about 1:14 for iron and about 1:5 for titanium. Those types for which the number is sufficient to give the comparison some weight are in the same ratios. There seems to be no undue proportion of any one type among the enhanced lines, considered as a whole.

Since the triplets appear to be representative, and as their magnitudes of separation can be handled most readily, Table 9 is arranged to compare the values of $\Delta\lambda/\lambda^2$ for enhanced and non-enhanced triplets. Triplets whose separation was not measurable are omitted, as are some non-enhanced triplets of very large separation, larger than is shown by any enhanced lines.

TABLE 9.—VALUES OF $\Delta\lambda/\lambda^2$ FOR ENHANCED AND NON-ENHANCED TRIPLETS.

RANGE OF $\Delta\lambda/\lambda^2$.	IRON.		TITANIUM.	
	ENHANCED.	NON-ENHANCED.	ENHANCED.	NON-ENHANCED.
0–1.0	1	2	0	9
1.0–1.4	3	40	6	30
1.4–1.8	7	94	26	99
1.8–2.2	5	93	11	66
2.2–2.6	3	84	4	26

On account of the small number of enhanced lines of iron, Table 9 serves to bring out little more than the distribution of the values of $\Delta\lambda/\lambda^2$. More enhanced lines are available for titanium, and in the study of these, two points are noteworthy: the absence of very small separations, and the disproportionately large number of enhanced triplets giving values from 1.4 to 1.8. This range includes the normal triplet at about 1.6, and the table shows that the separations of over half of the lines in question are close to this value. This is due in part to a condition which appears to be the only respect in which the enhanced lines are in a class by themselves as regards the Zeeman phenomenon. In the region from 3600 to 4600, which is rich in enhanced lines for titanium, the strongest enhanced lines were selected, 22 in number. These are lines showing a high degree of enhancement in the spark and are as a rule much stronger in the spark than any of the lines characteristic of the arc. A short exposure with a strongly condensed spark would show these lines almost alone. Of these 22 lines 17 are clear triplets; the remaining 5, with one exception, the weakest in the list, are of more complex character, These lines, with their intensity on the scale here used, their type of separation, and the values of $\Delta\lambda/\lambda^2$ for the triplets, are given in Table 10.

TABLE 10.—EFFECT OF THE MAGNETIC FIELD UPON THE STRONGER ENHANCED LINES OF TITANIUM.

λ	INTENSITY.	SEPARATION.	$\Delta\lambda/\lambda^2$	λ	INTENSITY.	SEPARATION.	$\Delta\lambda/\lambda^2$
3685.339	20	Triple	1.708	4302.085	5	Sextuple	.....
3741.791	10	Triple	1.878	4308.081	8	Octuple	.....
3759.447	20	Triple	2.038	4313.034	8	Sextuple	.....
3761.464	10	Triple	1.463	4338.084	10	Triple	1.312
3900.681	50	Triple	1.787	4395.201	20	Triple	1.796
3913.609	20	Triple	1.430	4443.976	15	Triple	1.509
4163.818	20	Triple	1.696	4468.663	15	Triple	1.702
4172.066	15	Triple	1.442	4501.445	15	Triple	1.471
4290.377	10	?	.....	4549.808	20	Triple	2.125
4294.204	10	Triple	1.958	4563.939	10	Triple	1.325
4300.211	8	?	.....	4572.156	20	Triple	1.526

The values of $\Delta\lambda/\lambda^2$ for the lines in Table 10 do not appear to be as closely related to the interval *a* as is usual among a like number of triplets taken at random. The measurements are usually of high weight, the photographs being made with self-induction in the spark circuit, and still there is a total lack of normal triplets, the values of $\Delta\lambda/\lambda^2$ being scattered rather uniformly from 1.3 to 2.1. The most we can conclude is that for titanium the strongest enhanced lines tend toward the triplet type, but not toward the simplest intervals of separation. When we extend the comparison to the weaker enhanced lines, many of which are of considerable strength in the arc, a large variety of types appears, with none predominating.

COMPARISON OF THE RESULTS FOR THE ZEEMAN EFFECT AND FOR PRESSURE DISPLACEMENT.

A summary of the theories on the possible connection between magnetic separation and pressure displacement is given on pp. 5-7. The data now at hand permit a considerable extension of the comparison made in my former paper (40). This is mainly in two directions. First, photographs of titanium arc spectra under pressure made in this laboratory by Mr. H. G. Gale have materially added to pressure measurements for this substance. Although this material has not yet been published by Mr. Gale, he has kindly permitted me to use his values in this comparison. Second, spectra given by the electric furnace under pressure have recently been obtained by me, and the preliminary results (63) bear on one of the questions involved in the present discussion.

In Tables 11 and 12 the values of the magnetic separations in the second column are taken directly from Tables 1 and 2 respectively. These values of $\Delta\lambda$ are for the *n*-components, the mean being taken when there are two or more pairs. Numerous changes have been made as compared to the former paper on this subject, due to better photographs being available.

The measurements of pressure displacements expressed in Ångström units are taken from the publications of Humphreys (41*b*) and of Duffield (64) for the iron spectrum. For titanium, some measurements are given by Humphreys, but most of the pressure values are from the photographs of Gale. The measurements by Humphreys in the third column are for a pressure of 42 atmospheres, his other measurements, for 69 and 101 atmospheres, being for only a part of the lines. For the iron spectrum, the displacements of Duffield for 41 atmospheres are given in the fourth column. For titanium, the measurements of Gale taken for 9 atmospheres total pressure were multiplied by 4.7 to bring them to the same order as those of Humphreys, assuming a direct proportion between displacement and pressure. Occasionally a line was not obtained by these observers for the given pressures, in which case an approximate value was deduced from the measurement for some other pressure and is accompanied by an interrogation point.

TABLE 11.—ZEEMAN SEPARATIONS AND PRESSURE DISPLACEMENTS FOR IRON.

λ	SEPARATION H= 16,000.	DISPLACEMENT.		RATIO SEP. TO DISPL.	CLASSES SEP. AND DISPL.
		42 ATM. (HUMPHREYS.)	41 ATM. (DUFFIELD.)		
3659.663	0.176	0.050	.....	3.54	S:S
3669.666	0.176	0.050	.....	3.54	S:S
3670.240	0.261	0.047	.....	5.55	S:S
3676.457	0.236	0.050	.....	4.72	S:S
3677.764	0.167	0.052	.....	3.21	S:S
3680.069	0.296	0.062	.....	4.77	S:M
3683.229	0.480	0.040	.....	12.00	L:S
3684.258	0.170	0.053	.....	3.21	S:S
3687.610	0.311	0.090	.....	3.46	M:M
3689.614	0.373	0.084	.....	4.44	M:M
3695.194	0.261	0.070	.....	3.73	S:M
3704.603	0.319	0.046	.....	6.93	M:S
3705.708	0.294	0.054	.....	5.44	S:S
3709.389	0.312	0.095	.....	3.28	M:M
3716.054	0.290	0.107	.....	2.71	S:L
3720.084	0.268	0.047	.....	5.70	S:S
3722.729	0.260	0.050	.....	5.20	S:S
3724.526	0.256	0.054	.....	4.74	S:S
3727.778	0.318	0.100	.....	3.18	M:M
3733.469	0.315	0.050	.....	6.30	M:S
3735.014	0.310	0.092	.....	3.37	M:M
3737.281	0.254	0.040	.....	6.35	S:S
3738.454	0.207	0.078	.....	2.65	S:M
3743.508	0.318	0.100?	.....	3.18	M:M
3745.717	0.228	0.050	.....	4.56	S:S
3746.058	.....	0.050	.....	....	O:S
3748.408	0.214	0.040	.....	5.35	S:S
3749.631	0.289	0.085	.....	3.40	S:M
3758.375	0.269	0.090	.....	2.99	S:M
3763.945	0.218	0.095	.....	2.29	S:M
3765.689	0.228	0.106	.....	2.15	S:L
3767.341	.....	0.118	.....	....	O:L
3788.046	0.326	0.090	.....	3.62	M:M
3795.147	0.325	0.093	.....	3.49	M:M
3798.655	0.326	0.085	.....	3.84	M:M
3799.693	0.326	0.075	.....	4.35	M:M
3805.486	0.204	0.092	.....	2.22	S:M
3813.100	0.203	0.058	.....	3.50	S:S
3815.987	0.264	0.110	.....	2.40	S:L
3820.586	0.282	0.125	.....	2.26	S:L
3824.591	0.345	0.040	.....	8.63	M:S
3826.027	0.274	0.090	.....	3.04	S:M
3827.980	0.225	0.102	.....	2.20	S:L
3834.364	0.248	0.110	.....	2.25	S:L

Table 11.—Zeeman Separations and Pressure Displacements for Iron—Continued.

λ	Separation H= 16,000.	Displacement.		Ratio Sep. to Displ.	Classes Sep. and Displ.
		42 atm. (Humphreys.)	41 atm. (Duffield.)		
3840.580	0.221	0.090	.....	2.46	S:M
3841.195	0.164	0.100	.....	1.64	S:M
3850.118	.....	0.082	.....	....	O:M
3856.524	0.341	0.038	.....	8.97	M:S
3860.055	0.341	0.042	.....	8.12	M:S
3865.674	0.343	0.103	.....	3.33	M:L
3872.639	0.284	0.108	.....	2.63	S:L
3878.720	0.346	0.044?	.....	7.86	M:S
3886.434	0.348	0.056	.....	6.21	M:S
3887.196	0.335	0.073	.....	4.59	M:M
3888.671	0.264	0.089	.....	2.97	S:M
3893.542	0.269	0.072	.....	3.74	S:M
3895.803	0.347	0.030	.....	1.16	M:S
3899.850	0.349	0.036	.....	9.69	M:S
3903.090	0.278	0.095	.....	2.93	S:M
3904.052	0.233	0.056	.....	4.16	S:S
3906.628	0.347	0.050	.....	6.94	M:S
3920.410	0.349	0.033	.....	10.58	M:S
3923.054	0.351	0.032	.....	10.96	M:S
3928.075	0.352	0.038	.....	0.92	M:S
3930.450	0.352	0.047	.....	0.75	M:S
3948.925	0.234	0.050	.....	4.68	S:S
3950.102	0.348	0.066	.....	5.27	M:M
3956.819	0.289	0.036	.....	8.03	S:S
3969.413	0.354	0.089	.....	3.98	M:M
3977.891	0.441	0.042	.. ..	10.98	L:S
3981.917	0.240	0.060?	.....	4.00	S:S
3984.113	0.216	0.085	.....	2.54	S:M
3986.321	0.196	0.061	.....	3.21	S:M
3997.547	0.266	0.048	.....	5.54	S:S
3998.205	0.226	0.066	.....	3.42	S:M
4005.408	0.461	0.103	.....	4.48	L:L
4009.864	0.377	0.040	.....	9.42	M:S
4014.677	0.250	0.050	.....	5.00	S:S
4017.308	0.397	0.062	.....	6.40	M:M
4022.018	0.272	0.037	.....	7.35	S:S
4045.975	0.298	0.103	0.082	2.89	M:L
4063.759	0.269	0.107	0.082	2.51	S:L
4071.908	0.170	0.092	0.086	1.85	S:M
4107.649	0.397	0.060	.....	6.62	M:S
4109.953	0.285	0.062	.....	4.60	S:M
4118.708	0.271	0.085	0.099	3.19	S:M
4127.767	0.196	.....	0.082	2.39	S:M
4132.235	0.510	0.105	0.108	4.86	L:L
4134.840	0.303	0.055?	0.086	5.51	M:S
4143.572	0.280	.....	0.095?	....	S:M
4144.038	0.393	0.116	0.099	3.97	M:L
4154.667	0.379	.....	0.086	4.41	M:M
4156.970	0.367	0.064?	0.065	5.73	M:M
4175.806	0.296	.....	0.065	4.55	S:M
4181.919	0.339	0.070?	.....	4.84	M:M
4185.058	0.390	0.040	0.047	9.75	M:S
4187.204	0.395	.....	0.190	2.08	M:L
4187.943	0.402	.....	0.431	0.93	L:L
4191.595	0.402	.....	0.310	1.30	L:L
4195.492	0.320	.....	Large	....	M:L
4196.372	0.359	.....	Large	....	M:L
4198.494	0.383	.....	Large	....	M:L
4199.267	0.276	0.073	0.065	3.78	S:M
4202.198	0.323	0.071	0.078	4.14	M:M
4204.101	0.373	.....	0.060	6.22	M:S
4210.494	0.806	.....	0.157	5.13	L:L
4219.516	0.284	0.074	0.078	3.84	S:M
4222.382	0.475	.....	0.358	1.33	L:L
4227.606	0.309	.....	0.431	0.72	M:L
4233.772	0.532	0.240	0.370	2.22	L:L
4236.112	0.452	0.274	0.405	1.65	L:L
4245.422	0.493	0.060	.....	8.22	L:S
4250.945	0.246	0.089	0.082	2.76	S:M
4260.640	0.423	0.246	0.177	1.72	L:L
4271.934	0.341	0.083	0.069	4.11	M:M
4282.566	0.310	0.043	0.056	7.21	M:S
4294.301	0.319	0.084	0.086	3.80	M:M
4299.410	0.406	.....	0.313	1.30	L:L
4308.081	0.320	0.090	0.060	3.56	M:M
4315.262	0.517	0.036	0.041	14.36	L:S
4325.939	0.245	0.097	.....	2.52	S:M
4337.216	0.264	0.090	0.082	2.93	S:M
4352.908	0.416	0.052	0.056	8.00	L:S
4367.749	0.311	0.060	.....	5.18	M:S
4369.941	0.282	0.055	0.060	5.13	S:S
4376.107	0.424	0.039	0.047	10.87	L:S
4383.720	0.332	0.125	0.060	2.66	M:L
4404.927	0.334	0.110	0.056	3.04	M:L
4407.871	0.631	0.180	.....	3.51	L:L
4408.582	0.488	0.160	.....	3.05	L:L
4415.293	0.338	0.087	0.078	3.89	M:M
4422.741	0.293	0.065	0.046	4.51	M:M
4427.482	0.430	0.055	0.043	7.82	L:S
4430.785	0.719	0.190	0.159	3.78	L:L
4442.510	0.485	0.190	0.164	2.55	L:L
4443.365	0.170	0.060	0.060	2.83	S:S
4447.892	0.585	0.180	0.172	3.25	L:L
4454.552	0.445	0.080	.....	5.56	L:M
4459.301	0.449	0.160	0.172	2.81	L:L
4461.818	0.435	0.060	0.039	7.25	L:S
4466.727	0.343	0.056	0.046	6.12	M:S
4476.185	0.306	0.072	0.042	4.25	M:M
4494.738	0.302	0.200	0.168	1.51	M:L
4528.798	0.358	0.172	0.172	2.08	M:L
4531.327	0.400	0.075	0.078	5.32	L:M
4548.024	0.311	0.097	.....	3.21	M:M
4592.840	0.416	0.110	.....	3.78	L:L
4603.126	0.566	0.093	.....	6.09	L:M
4647.617	0.392	0.070	.....	5.60	M:M
4691.602	0.358	0.070	.....	5.11	M:M
4710.471	0.242	0.060	.....	4.03	S:S
4736.963	0.426	0.085	.....	5.01	L:M
4787.003	0.409	0.076	.....	5.38	L:M
4789.849	0.352	0.080	.....	4.40	M:M
4859.928	0.564	0.390	.....	1.45	L:L
4871.512	0.336	0.420	.....	0.80	M:L
4878.407	1.092	0.400	.....	2.73	L:L
4919.174	0.591	0.375	.....	1.58	L:L
5171.778	0.521	0.075	.....	6.95	L:M
5195.113	0.457	0.080	.....	5.71	L:M
5269.723	0.501	0.083	.....	6.04	L:M
5328.236	0.470	0.100	.....	4.70	L:M
5371.734	0.413	0.095	.....	4.35	L:M
5397.344	0.630	0.080	.....	7.88	L:M
5405.989	0.341	0.100	.....	3.41	M:M
5429.911	0.607	0.085	.....	7.14	L:M
5434.740	.....	0.120	.....	....	O:L
5447.130	0.568	0.095	.....	5.98	L:M
5455.834	0.692	0.105	.....	6.59	L:L
5497.735	1.040	0.110	.....	9.45	L:L
5501.683	1.001	0.095	.....	10.54	L:M
5507.000	1.026	0.120	.....	8.55	L:L
5615.877	0.586	0.080	.....	7.33	L:M

TABLE 12.—ZEEMAN SEPARATIONS AND PRESSURE DISPLACEMENTS FOR TITANIUM.

λ	SEPARATION H=17,500.	DISPLACEMENT.		RATIO SEP. TO DISPL.	CLASSES SEP. AND DISPL.	λ	SEPARATION H=17,500.	DISPLACEMENT.		RATIO SEP. TO DISPL.	CLASSES SEP. AND DISPL.
		42 ATM. (HUMPHREYS.)	42 ATM. (GALE.)					24 ATM. (HUMPHREYS.)	42 ATM. (GALE.)		
3900.681	0.272	.....	0.212	1.28	S:L	4318.817	0.337	0.042	.....	8.02	M:S
3904.926	0.240	0.073	0.085	2.82	S:M	4326.520	0.403	.....	0.141	2.86	L:L
3913.609	0.219	.....	0.174	1.26	S:L	4338.084	0.247	.....	0.089	2.78	S:M
3914.477	0.352	.....	0.028	12.57	M:S	4346.278	0.453	.....	0.028	1.62	L:S
3921.563	0.426	.....	0.019	22.42	L:S	4360.644	0.348	.....	0.183	1.90	M:L
3924.673	0.292	.....	0.047	6.21	S:S	4394.093	0.325	.....	0.066	4.92	M:M
3926.465	0.247	.....	0.235	1.05	S:L	4395.201	0.347	.....	0.118	2.94	M:M
3930.022	0.362	.....	0.042	8.62	M:S	4417.450	0.381	.....	0.127	3.00	M:L
3947.918	0.098	.....	0.028	3.50	S:S	4421.928	0.289	.....	0.179	1.61	S:L
3948.818	0.186	0.045	0.075	2.48	S:M	4422.985	0.377	.....	0.113	3.34	M:M
3956.476	0.229	0.030	0.047	4.87	S:S	4426.201	0.318	.....	0.122	2.61	M:M
3958.355	0.287	0.045	0.080	3.59	S:M	4427.266	0.312	0.024?	0.070	4.46	M:M
3962.995	0.461	.....	0.042	10.98	L:S	4434.168	0.259	.....	0.174	1.49	S:L
3964.416	0.359	.....	0.038	9.45	M:S	4440.515	0.270	.....	0.141	1.91	S:L
3981.917	0.188	0.056	0.094	2.00	S:M	4443.976	0.298	.....	0.103	2.89	S:M
3982.630	0.469	.....	0.019	24.68	L:S	4449.313	0.388	.....	0.118	3.29	M:M
3989.912	0.275	0.049	0.103	2.67	S:M	4451.087	0.340	.....	0.122	2.79	M:M
3998.790	0.317	0.047	0.113	2.80	M:M	4453.486	0.210	.....	0.183	1.15	S:L
4009.079	0.347	0.055	0.028	12.39	M:S	4453.876	0.263	.....	0.108	2.43	S:M
4009.807	0.086	.....	0.038	2.26	S:S	4455.485	0.351	.....	0.193	1.82	M:L
4012.541	0.198	.....	0.042	4.71	S:S	4457.600	0.400	.....	0.193	2.07	L:L
4024.726	0.394	.....	0.038	10.37	M:S	4465.975	0.481	.....	0.122	3.94	L:M
4028.497	0.269	.....	0.085	3.16	S:M	4468.663	0.340	.....	0.216	1.57	M:L
4035.976	0.354	.....	0.244	1.45	M:L	4471.408	0.601	.....	0.089	6.75	L:M
4055.189	0.395	.....	0.085	4.65	M:M	4475.026	0.509	.....	0.362	1.41	L:L
4060.415	0.395	.....	0.075	5.27	M:M	4479.879	0.829	.....	0.132	6.28	L:L
4064.362	0.396	.....	0.094	4.21	M:M	4480.752	0.611	.....	0.136	4.49	L:L
4065.239	0.395	.....	0.047	8.40	M:S	4481.438	0.548	.....	0.113	4.85	L:M
4078.631	0.395	.....	0.019	20.79	M:S	4489.262	0.612	.....	0.146	4.19	L:L
4082.589	0.398	.....	0.061	6.52	M:M	4501.445	0.298	.....	0.216	1.38	S:L
4112.869	0.301	.....	0.047	6.40	M:S	4512.906	0.501	.....	0.132	3.80	L:L
4151.129	0.305	.....	0.207	1.47	M:L	4518.198	0.498	.....	0.136	3.66	L:L
4159.805	0.263	.....	0.160	1.64	S:L	4518.866	0.220	.....	0.094	2.34	S:M
4163.818	0.294	.....	0.179	1.64	S:L	4522.974	0.502	.....	0.146	3.44	L:L
4171.213	0.210	.....	0.146	1.44	S:L	4527.490	0.495	.....	0.132	3.75	L:L
4172.066	0.251	.....	0.188	1.34	S:L	4533.419	0.469	0.176	0.150	3.13	L:L
4186.280	0.282	.....	0.056	5.04	S:S	4534.953	0.449	0.124	0.160	2.81	L:L
4203.620	0.457	.....	0.179	2.55	L:L	4535.741	0.424	.....	0.136	3.12	L:L
4272.701	0.364	.....	0.075	4.85	M:M	4536.094	0.323	.....	0.113	2.86	M:M
4276.587	0.443	.....	0.136	3.26	L:L	4536.222	.....	.....	0.160	....	O:L
4278.390	0.304	.....	0.188	1.62	M:L	4544.864	0.502	0.080	0.136	6.27	L:L
4281.530	0.664	.....	0.061	1.09	L:M	4548.938	0.560	.....	0.150	3.73	L:L
4282.860	0.244	.....	0.132	1.85	S:L	4549.808	0.440	.....	0.226	1.95	L:L
4285.164	0.566	.....	0.160	3.54	L:L	4552.632	0.510	.....	0.132	3.86	L:L
4286.168	0.400	0.103	0.099	4.04	L:M	4555.662	0.506	.....	0.132	3.83	L:L
4287.566	0.421	0.087	0.118	3.57	L:M	4562.814	0.424	.....	0.038	1.12	L:S
4289.237	0.370	.....	0.108	3.42	M:M	4563.939	0.276	.....	0.150	1.84	S:L
4290.377	0.284	.....	0.216	1.31	S:L	4572.156	0.319	.....	0.235	1.36	M:L
4291.114	0.441	0.115	0.103	4.28	L:M	4617.452	0.404	.....	0.136	2.97	L:L
4294.204	0.361	.....	0.136	2.65	M:L	4623.279	0.379	.....	0.118	3.21	M:M
4295.914	.....	0.100	0.103	....	O:M	4629.521	0.527	.....	0.169	3.12	L:L
4298.828	0.218	.....	0.118	1.85	S:M	4682.088	0.399	0.077	.....	5.18	M:M
4299.410	0.430	.....	0.103	4.17	L:M	4691.523	0.441	0.080	.....	5.51	L:M
4299.803	0.356	.....	0.103	3.46	M:M	4758.308	0.382	0.067	.....	5.70	M:M
4300.211	0.367	.....	0.136	2.70	M:L	4759.463	0.430	0.092	.....	4.67	L:M
4300.732	0.265	0.104	0.099	2.68	S:M	4841.074	0.390	0.029	.....	13.44	M:S
4301.158	0.350	0.110	0.113	3.10	M:M	4981.912	0.481	0.077	.....	6.25	L:M
4302.085	0.368	.....	0.160	2.30	M:L	4991.247	0.458	0.135	.....	3.39	L:L
4306.078	0.367	0.104	0.113	3.25	M:M	4999.689	0.413	0.120	.....	3.44	L:M
4313.034	0.449	.....	0.216	2.08	L:L	5007.398	0.339	0.150?	.....	2.26	M:L
4314.964	0.424	.....	0.146	2.90	L:L	5013.479	0.455	0.056	.....	8.12	L:S

The fifth and sixth columns contain ratios of Zeeman separation to pressure displacement, the one numerical, the other of letters denoting the order of magnitude. In the numerical ratios for iron the values of Humphreys are used for the sake of uniformity, those of Duffield for an almost equal pressure being taken when a line was not measured by the former. In the case of titanium the values of Gale are the more numerous and are used in the ratios when possible. The letters S, M and L in the sixth column stand for small, medium and large values, respectively, of separation and displacement. The limits covered by these classes are as follows:

	Separation.	Displacement.	
		Iron.	Titanium.
S............	<0.300	<0.060	<0.060
M............	0.300–0.400	0.060–0.100	0.060–0.125
L............	>0.400	>0.100	>0.125

The reasons for this classification are given later.

The question as to whether there is a close proportionality between magnetic separation and pressure shift is decided in a definite manner by the sixth column in Tables 11 and 12, giving the numerical ratio of separation to displacement. The separations for each spectrum are taken for a constant field and the displacements for a constant pressure. The probable errors in measurement can explain only in a very small degree the larger differences in these ratios. For iron the ratio-values run from 0.72 to 14.36, for titanium from 1.05 to 22.42. The distribution between these limits is such that any range which might reasonably be assumed as due to poor measurements covers but a fraction of the lines. Thus in Table 11, ratios ranging from 2.00 to 5.00 take in 90 out of 173 lines, or 52 per cent; the same range for titanium includes 67 out of 122 lines, or 55 per cent. The range from 3.00 to 5.00 in the two spectra covers 35 and 34 per cent respectively.

The lack of constancy in the ratio being apparent, the question arises as to whether there is any real connection between separation and displacement. A broad classification of the values in order of magnitude may be of service in this connection. For this purpose the separation and displacement values are classified as small, medium and large, the range for each class being given above. The ratios showing the comparative magnitudes of separation and displacement for each line are given in the sixth column of the tables. The displacement measures for titanium run in general larger than for iron, so that a higher point of division between the medium and large classes is chosen. The following summary of the data will show to what extent a general agreement exists between the Zeeman and pressure phenomena.

The ratios of classes from Tables 11 and 12 enable us to form Table 13, in which the 173 iron and 122 titanium lines are placed in three main groups. Group 1 consists of the ratios S : S, M : M, L : L, and shows that the separation and displacement for the corresponding lines are relatively of the same order. Group 2 contains those lines for which separation and displacement are not in the same, but in adjacent, classes; while for Group 3 the separation and displacement are of very different magnitude, one small and the other large. Those lines which show no Zeeman effect, but distinct pressure displacement, are also in Group 3, the letter O being associated with S, M, or L according to the magnitude of the displacement.

It will be seen that 44 per cent of the iron lines are in good agreement as to order of magnitude, 44 per cent show a probable discordance, while 12 per cent strongly contradict the hypothesis of equality of relative magnitude. Titanium shows a somewhat larger proportion of its lines in poor agreement as to separation and displacement. This indicates clearly that the two phenomena are not very closely related as regards size of one increasing with size of the other. The large number of lines in Group 2 renders any positive conclusion difficult on account of the possible influence of errors of measurement.

Trials with other limits for the small, medium and large classes have shown that the group percentages are not materially altered, as this results in a transfer back and forth of lines near the limits chosen. An attempt to reduce Group 2 was made by taking all those lines which had one or both values so near the limit of the class that the error of measurement, if in the favorable direction, might have put the two values into the same class and so have brought the line into Group 1. Lines of complex Zeeman separation were also treated in this way; 35 iron lines were thus selected, which when added to Group 1 as given in Table 13 raised its total to 64 per cent of the whole. This number, then, may be in fair agreement as to order of magnitude, while the remaining 36 per cent are divergent beyond the errors of measurement and in some distances widely different. This last device is of course not a fair treatment of the data, since the error of measurement is as likely to move the values wider apart as closer together, and if the same treatment had been applied to the lines of Group 1, some of them would have moved into Group 2. However, giving the agreement hypothesis the benefit of the doubt, the proportions of 64 and 36 per cent appear to be the most favorable that can be gotten out of the list of iron lines.

TABLE 13.—SUMMARY OF CLASSES.

IRON.				TITANIUM.			
RATIO OF MAG.	NO. OF LINES.	GROUP TOTAL.	GROUP PERCENTAGE.	RATIO OF MAG.	NO. OF LINES.	GROUP TOTAL.	GROUP PERCENTAGE.
Group 1				Group 1			
S:S	24	76	44	S:S	6	53	43
M:M.......	29			M:M.......	21		
L:L........	23			L:L........	26		
Group 2				Group 2			
S:M........	27	77	44	S:M	12	46	38
M: S.	22			M:S	10		
M:L.	13			M:L	12		
L:M........	15			L:M........	12		
Group 3				Group 3			
S:L	8	20	12	S:L	15	23	19
L:S	8			L:S.........	6		
O:S	1			O:S	0		
O:M........	1			O:M	1		
O:L........	2			O:L........	1		

In Group 3 we have those lines for which either separation or displacement is small and the other large, and in addition 4 lines of iron and 2 of titanium which appear to be unaffected by the magnetic field, while they show a variety of displacements, in some cases large. These offer examples of ability to respond to one displacing agency and not to the other.

A closer quantitative comparison is afforded by taking the average separations and displacements for large groups of lines. This is done in Tables 14 and 15. The method in forming Table 14 was to make a list of all pressure displacements classified as small, place opposite them the Zeeman separations for the same lines, and take the mean of each list for comparison of the magnitude of the two effects. Means were formed in the same way for lines of medium and large displacement. The ratios of mean separation to mean displacement can then be compared. In obtaining the results for each class, means were formed for the lines in three groups according to wave-length. The whole table thus gives a comparison of the means for the several groups, and also an indication as to how the means for both separation and displacement change with the wave-length.

Table 15 was made in the same way as Table 14, except that here the class of Zeeman separation, small, medium, or large, was taken as the basis, and the corresponding pressure displacements used for a comparison of means.

TABLE 14.—MEANS OF SEPARATION AND DISPLACEMENT CLASSIFIED ACCORDING TO AMOUNT OF DISPLACEMENT.

	IRON.					TITANIUM.				
	RANGE OF λ.	NO. OF LINES.	MEANS.		RATIO SEP. DISPL.	RANGE OF λ.	NO. OF LINES.	MEANS.		RATIO SEP. DISPL.
			SEP.	DISPL.				SEP.	DISPL.	
Displacement: Small........	3660–4000	35	0.290	0.046	6.30	3900–4000	9	0.339	0.034	9.97
	4000–4500	18	0.361	0.051	7.08	4000–4500	10	0.319	0.038	8.39
	4500–5600	1	0.242	0.060	4.03	4500–5000	3	0.423	0.041	10.32
Total of lines and weighted means....................		54	0.313	0.048	6.52		22	0.340	0.037	9.19
Displacement: Medium	3660–4000	30	0.272	0.084	3.24	3900–4000	6	0.249	0.092	2.71
	4000–4500	22	0.297	0.080	3.71	4000–4500	30	0.378	0.099	3.82
	4500–5600	19	0.478	0.085	5.62	4500–5000	9	0.385	0.093	4.14
Total of lines and weighted means....................		71	0.335	0.083	4.04		45	0.362	0.097	3.73
Displacement: Large	3660–4000	8	0.221	0.109	2.03	3900–4000	3	0.246	0.207	1.19
	4000–4500	24	0.452	0.207	2.18	4000–4500	31	0.379	0.175	2.16
	4500–5600	9	0.679	0.245	2.77	4500–5000	19	0.446	0.157	2.84
Total of lines and weighted means....................		41	0.462	0.196	2.36		53	0.396	0.170	2.33

TABLE 15.—MEANS OF SEPARATION AND DISPLACEMENT CLASSIFIED ACCORDING TO AMOUNT OF SEPARATION.

	IRON.					TITANIUM.				
	RANGE OF λ.	NO. OF LINES.	MEANS.		RATIO SEP. DISPL.	RANGE OF λ.	NO. OF LINES.	MEANS.		RATIO SEP. DISPL.
			SEP.	DISPL.				SEP	DISPL.	
Separation: Small	3660–4000	42	0.240	0.072	3.33	3900–4000	11	0.230	0.107	2.15
	4000–4500	18	0.258	0.077	3.22	4000–4500	19	0.247	0.128	1.93
	4500–5600	1	0.242	0.060	4.03	4500–5000	3	0.265	0.153	1.73
Total of lines and weighted means....................		61	0.246	0.073	3.37		33	0.243	0.123	1.98
Separation: Medium	3660–4000	28	0.337	0.065	5.18	3900–4000	4	0.348	0.055	6.33
	4000–4500	24	0.346	0.098	3.53	4000–4500	34	0.360	0.114	3.16
	4500–5600	8	0.356	0.136	2.62	4500–5000	7	0.362	0.113	3.20
Total of lines and weighted means....................		60	0.343	0.088	3.90		45	0.359	0.108	3.32
Separation: Large..........	3660–4000	2	0.460	0.041	11.22	3900–4000	3	0.452	0.027	1.67
	4000–4500	23	0.495	0.173	2.86	4000–4500	18	0.519	0.138	3.76
	4500–5600	20	0.629	0.137	4.59	4500–5000	21	0.471	0.127	3.71
Total of lines and weighted means....................		45	0.553	0.151	3.66		42	0.490	0.125	3.92

In Table 14 the ratios of classes given by the weighted means for the three magnitudes of displacement are M : S, M : M, and L : L for both iron and titanium. Table 15 gives for the three magnitudes of separation the ratios S : M, M : M, L : L, for both elements. There is thus good agreement as to magnitudes except for the first class in each table. A large proportion of the lines for this class come from the region below λ4000 and there is a sufficient scattering of high values for both separation and displacement to put the means into different classes when formed in this way. The behavior of the ratios of weighted means in the two tables is interesting. Those in Table 15 decrease very nearly in the ratio 3 : 2 : 1 for the three classes in the iron table, and about 9 : 4 : 2 for titanium, showing that the displacements increase in size much faster than the separations. The same material is used in Table 15, but here we find an approximate constancy for iron and a gradual increase for titanium. It is probable that the change as shown in Table 14 is a real one and that it is obscured in Table 15 by the large difference in range of values of separations and displacements. The limits of this range are in the ratio of about 1 to 3 for the separations (omitting a few extreme values) and about 1 to 10 for the displacements. Thus, in Table 14, when the displacements are grouped so as to increase in magnitude, there is a much smaller variation among corresponding values of separation than we have among the displacement values when the separations are graded as in Table 15. The widely divergent values of displacement scattered through Table 15 would thus act to make the ratios of means more or less discordant.

A classification by Duffield (64a) may be used in comparing the displacements measured by him with the corresponding Zeeman separations for iron. He forms three main groups according to amount of displacement. Table 16 gives the mean separation and displacement for each of these groups, at first singly, then combined so as to form two groups with more lines in each.

TABLE 16.—MEANS OF SEPARATION AND DISPLACEMENT FOR DUFFIELD'S DISPLACEMENT GROUPS.

	NO. OF LINES.	MEAN SEP.	MEAN DISPL.	CLASSES SEP. AND DISPL.
Group I				
Unreversed	26	0.335	0.064	M:M
Reversed	13	0.317	0.077	M:M
Group II	6	0.483	0.168	L:L
Group III	10	0.400	0.319	L:L
Total of Group I	39	0.329	0.068	M:M
Totals of Groups I and II	16	0.431	0.262	L:L

We see that separation and displacement are of the same order of magnitude throughout. In the last two lines the larger number of values gives means of higher weight. These means show as before that a much larger range is covered by the displacements than by the separations.

Two additional points are to be considered in this comparison. The first is the rate of increase of the two effects with magnetic field and pressure, respectively. Duffield found that the displacements of lines belonging to the three groups treated in Table 16 have very different rates of increase with increase of pressure, the lines of Group III showing the most rapid change. A corresponding phenomenon in the Zeeman effect would mean a different rate of increase of separation with field-strength for different lines. We are not certain that this does not exist, since the proportionality of separation to field-strength has been established by careful measurement for only a very few lines, but no evidence of a difference for different sets of lines has thus far been presented.

The second point is the relation of the variation of separation and displacement with the wave-length. In Tables 14 and 15 the division into regions of wave-lengths shows the distribution of magnitudes in these regions. Following down the columns headed "No. of Lines" in each table, we see that the proportion of small values for both separation and displacement is greater in the region of short wave-lengths.

For the medium and large values in each table, the proportion of lines increases in the region of greater wave-length, this being very decided for the "large" group. Thus there is a clear increase in magnitude of both separation and displacement as the wave-length increases. The lines here compared seem to be representative of the spectrum, as the same relation holds in the complete Zeeman tables, which contain a much larger number of lines for this range of wave-length.

When pressure measurements of high accuracy are available for an extended region of wave-length, the rate of variation with the wave-length will appear, and the closeness of agreement with the relation found for iron and titanium, namely, that the magnetic separation increases proportionally with the square of the wave-length (p. 54), will afford strong evidence concerning the common physical basis of the two phenomena. An attempt at a comparison of this sort has been made by the author in a recent paper (63) on the effect of pressure upon electric-furnace spectra. The displacements of iron lines given by the electric furnace for a pressure of 9 atmospheres were measured for two regions 1000 Å apart, from λ4050 to λ4450 and from λ5050 to λ5450. The list for the latter region did not include as many of the weaker lines, whose displacements are often large, as was available for the blue region, so that a comparison of the means of all displacements would not have been fair. It seemed best to limit this preliminary comparison to those lines in each region which show the same general behavior in various light sources. In the furnace they appear at low temperatures and show reversal with strong widening under pressure. They are lines which, although not connected by series relations, show such similarity in their response to the excitations of furnace, arc, and spark that the vibrating particles which produce them can be assumed to have many points of similarity.

Fifteen lines of this character in the blue region were compared with nine similar lines in the green. The mean pressure displacement for the two sets was found to be almost identical, being 0.058 Å for the blue and 0.060 Å for the green lines. The magnetic separations of the same lines, taken from Table 1, give mean values of 0.330 Å and 0.520 Å, respectively, for the blue and green regions, an increase of 60 per cent for a difference of wave-length of about 1000 Å. The evidence from these selected lines is, therefore, against a close connection between the magnetic and pressure phenomena. Measurements for the arc under pressure, however, show a more frequent occurrence of large displacements as we pass toward greater wave-lengths, and more complete measurements will show the rate of change.

Summarizing the comparison here presented, it may be said that there is a fair agreement between magnitude of magnetic separation and pressure displacement for the lines of iron and titanium when the means of large groups are considered. The number and character of the lines not in agreement, however, show that the correspondence is not close enough to justify preferring any one of the theories for the pressure effect on this ground, or to predict the effect upon a given line of one influence from that observed for the other. The degree of concordance which we have could perhaps result entirely from the fact that the magnitude of each effect increases with the wave-length. This does not prove a close physical relation, since any theory of the pressure effect that might be offered would probably involve a change with the wave-length. A comparison of the rates of change of the two effects appears to be a more promising line of investigation than an extension of the method followed for iron and titanium; as the number of lines treated for those spectra is sufficient to show clearly the degree of correspondence.

SUMMARY OF RESULTS.

The leading features in this investigation may be summarized as follows:

1. The effect of a magnetic field upon the spark spectra of iron and titanium has been studied for a total number of 1120 lines between the limits λ3660 and λ6743. The character of the magnetic separation is given, with weighted measurements as complete as was permitted by the magnetic fields available.

2. The types of resolution, ranging from lines unaffected by the magnetic field to those having thirteen and possibly more components, have been classified and the important features of each class have been discussed.

3. The relation of the measured separations to the "normal interval"

$$a = \frac{e}{m} \cdot \frac{H}{4\pi v}$$

has been studied for all types of resolution. A large majority of the separations of triplets and quadruplets show a close relation to this interval, while the generality with which the more complex types show the spacing of their components to be simply related to this interval indicates a full confirmation of Runge's law.

4. Many cases of "magnetic duplicates," i.e., lines exactly similar in resolution, with the same intervals between components, have been found among the more complex types, indicating close similarity in the light vibrations which give rise to these lines. Large groups of lines showing triplet separation are similar in this respect.

5. The large range of wave-length covered has made it possible to observe the rate of increase of magnetic separation with the wave-length. This increase is such that the mean value of $\Delta\lambda/\lambda^2$ for successive intervals throughout this range shows a close approach to constancy for both iron and titanium, with no systematic variation. The conclusion is that for these spectra the mean separation of Zeeman components varies as the square of the wave-length.

6. Cases of unsymmetrical separation of Zeeman components, so distinct as to be classed as abnormal, have been pointed out. The theory of Voigt concerning a slight dissymmetry in the intensity and spacing of the components of triplets has been tested for a number of iron lines, with the result that this effect appears to be real in many cases, although some lines fail to show such a difference.

7. The enhanced lines of the two elements have been compared with those showing no enhancement in the spark, both as to type and magnitude of separation. The only difference between the behavior of the two classes in the magnetic field appears to be that among the stronger enhanced lines of titanium the triplet type strongly predominates, the separations usually being of medium amount and not closely related to the interval *a*.

8. On account of a possible similarity between the actions of the magnetic field and of pressure around the light source as displacing agencies, a detailed comparison has been made of the magnetic separations and corresponding pressure displacements for these spectra. It was proved that a close correspondence does not exist, but there is a general agreement as to magnitude of the two effects when the means for large numbers of lines are considered.

In conclusion, I wish to acknowledge my great obligations to Mr. Hale for his unfailing support and interest in the equipment and development of the physical laboratory and for much advice as to the conduct of the investigations. A great deal of credit is due also to Miss Wickham and to Miss Griffin for their careful and often difficult work in the measurement and reduction of the photographs. The large number of spectrograms required to do justice to the iron spectrum, in particular, increased the work of measurement out of proportion to the total number of lines treated.

BIBLIOGRAPHICAL REFERENCES.

1. A. Cotton, "Le Phénomène de Zeeman," *Scientia*, (5), Paris, 1899; (*a*), p. 52.

2. H. Kayser, "Handbuch der Spectroscopie," **2**, IX, 1902; (*a*), pp. 635, 636; (*b*), p. 620; (*c*), p. 672.

3. W. Voigt, "Magneto- und Elektrooptik," Leipzig, 1908, (*a*), p. 86; (*b*), Ch. III.

4. H. A. Lorentz, "The Theory of Electrons," Leipzig, 1909; (*a*), p. 109.

5. P. Zeeman, "Over den Invloed eener Magnetisatie op den aard van het door een Stof uitgezonden Licht," *Verslagen Koninklijke Akademie Amsterdam*, **5**, 181, 242, 1896; *Philosophical Magazine*, (5), **43**, 226, 1897; *Astrophysical Journal*, **5**, 332, 1897.

   "Over Doubletten en Tripletten in het Spectrum teweeg gebracht door uitwendige Magnetische Krachten," *Verslagen Koninklijke Akademie Amsterdam*, **6**, 12, 99, 260, 1897; *Philosophical Magazine*, (5), **44**, 255, 1897.

   "Metingen over Stralingsverschijnselen in het Magnetisch Veld, "*Verslagen Koninklijke Akademie Amsterdam*, **6**, 408, 1897; *Philosophical Magazine*, (5), **45**, 197, 1898.

6. A. A. Michelson, "Radiation in a Magnetic Field," *Philosophical Magazine*, (5), **44**, 109, 1897; **45**, 348, 1898; *Astrophysical Journal*, **6**, 48, 1897; **7**, 131, 1898.

7. Th. Preston, "Radiation Phenomena in a Strong Magnetic Field," *Philosophical Transactions Royal Society Dublin*, (2) **6**, 385, 1897.

8. A. Cornu, "Sur quelques Résultats nouveaux relatifs au Phénomène découvert par M. le Dr. Zeeman," *Comptes Rendus*, **126**, 181, 1898.

9. H. Becquerel et H. Deslandres, "Contribution à l'Étude du Phénomène de Zeeman," *Comptes Rendus*, **126**, 997, 1898.

10. "Observations nouvelles sur le Phénomène de Zeeman," *Comptes Rendus*, **127**, 18, 1898.

11. J. S. Ames, R. F. Earhart, and H. M. Reese, "Notes on the Zeeman Effect," *Astrophysical Journal*, **8**, 48, 1898.

12. H. M. Reese, "An Investigation of the Zeeman Effect," *Astrophysical Journal*, **12**, 120, 1900.

13. N. A. Kent, "Notes on the Zeeman Effect," *Astrophysical Journal*, **13**, 289, 1901.

14. H. A. Lorentz, "Ueber den Einfluss magnetischer Kräfte auf Lichtemission," *Annalen der Physik*, (3), **63**, 278, 1897.

    "Beschouwingen over den Invloed van een magnetisch Veld op de Uitstraling van Licht," *Verslagen Koninklijke Akademie Amsterdam*, **7**, 113, 1898; *Astrophysical Journal*, **9**, 37, 1899.

15. J. Larmor, "On the Theory of the Magnetic Influence on Spectra," *Philosophical Magazine*, (5), **44**, 503, 1897.

16. W. Voigt, "Zur Theorie der magneto-optischen Erscheinungen," *Annalen der Physik*, (3), **67**, 345, 1899.

    "Weiteres zur Theorie des Zeemaneffektes," *Annalen der Physik*, (3), **68**, 353, 1899.

17. A. A. Robb, "Beiträge zur Theorie des Zeemaneffektes," *Annalen der Physik*, (4), **15**, 107, 1904.

18. C. Runge und F. Paschen, "Ueber die Strahlung des Quecksilberlichts im magnetischen Felde," *Abhandlungen Akademie der Wissenschaften Berlin*, 1902, Anhang I.

19. A. Färber, "Ueber das Zeeman-Phänomen," *Annalen der Physik*, (4), **9**, 886, 1902.

20. P. Weiss et A. Cotton, "Mesure du Phénomène de Zeeman pour les trois Raies Bleues du Zinc," *Journal de Physique*, (4), **6**, 429, 1907.

21. F. Paschen, "Ueber die absolute Messung des Zeemaneffektes," *Physikalische Zeitschrift*, **8**, 522, 1907.

22. A. Stettenheimer, "Absolute Messungen des Zeeman-Phänomens," *Annalen der Physik*, (4), **24**, 384, 1907.

23. Th. Preston, "Radiation Phenomena in the Magnetic Field," *Nature*, **59**, 224, 1899.

    "General Law of the Phenomena of Magnetic Perturbations of Spectral Lines," *Nature*, **59**, 248, 1899.

    "Radiating Phenomena in a Strong Magnetic Field," *Philosophical Transactions Royal Society Dublin*, (2), **7**, 7, 1899; *Report British Association*, 1899, p. 63; *Nature*, **61**, 11, 1899.

24. C. Runge und F. Paschen, "Ueber die Zerlegung einander entsprechender Serienlinien im magnetischen Felde," *Sitzungsberichte Akademie der Wissenschaften Berlin*, 1902, 380, 720.

25. C. Runge und J. Precht, "Ueber die Magnetische Zerlegung der Radiumlinien," *Sitzungsberichte Akademie der Wissenschaften Berlin*, 1904, 417.

26. W. Miller, "Zeemaneffect an Magnesium, Calcium, Strontium, Zink, Cadmium, Mangan und Chrom," *Annalen der Physik*, (4), **24**, 105, 1907.

27. W. Lohmann, "Beiträge zur Kenntnis des Zeeman-Phänomens," Dissertation, Halle, 1907; *Zeitschrift für Wissenschaftliche Photographie*, **6**, 41, 1908.

28. B. E. Moore, "Upon the Magnetic Separation of the lines of Barium, Yttrium, Zirconium, and Osmium," *Astrophysical Journal*, **28**, 1, 1908; *Annalen der Physik*, (4), **25**, 309, 1908.

    "Upon the Separation of the Spectral Lines of Thorium in the Magnetic Field," *Astrophysical Journal*, **30**, 144, 178, 1909.

29. C. Runge, "Ueber die Zerlegung von Spektrallinien im magnetischen Felde," *Physikalische Zeitschrift*, **8**, 232, 1907.

30. P. Zeeman, "Some Observations concerning an Asymmetrical Change of the Spectral Lines of Iron, radiating in a Magnetic Field," *Verslagen Koninklijke Akademie Amsterdam*, **8**, 328, 1899.

31. P. Zeeman, "Magnetic Resolution of Spectral Lines and Magnetic Force," Second Part, *Verslagen Konkinklijke Akademie Amsterdam*, December, 1907.
    "New Observations concerning Asymmetrical Triplets," *Verslagen Koninklijke Akademie Amsterdam*, March, 1908.
    "Change of Wave-Length of the Middle Line of Triplets," *Verslagen Koninklijke Akademie Amsterdam*, May, 1908.
    "The Law of Shift of the Central Component of a Triplet in a Magnetic Field," *Verslagen Koninklijke Akademie Amsterdam*, January, 1909.

32. P. Gmelin, "Ueber die unsymmetrische Zertegung der gelben Zuecksilberlinie 5790 im magnetischen Felde," *Physikalische Zeitschrift*, 9, 212, 1908.

33. R. Jack, "Zeeman-Effekt an Wolfram und Molybdän," Dissertation Göttingen, 1908; *Annalen der Physik*, (4), 28, 1032, 1909; *Proceedings Royal Society Edinburgh*, 29, 75, 1908.

34. A. Dufour, "Observation faite parallèlement aux Lignes de Force des Dissymétries d'Intensités et de Positions des Composantes Magnétiques de quelques Raies d'Émission," *Le Radium*, 6, 298, 1909; *Comptes Rendus*, 148, 1594, 1909.
    "Sur les Triplets Magnétiques Dissymétriques," *Le Radium*, 7, 74, 1910.

35. W. Voigt, "Magneto- und Elektrooptik," IV Kap.

36. W. König. "Beobachtung des Zeeman'schen Phänomens," *Annalen der Physik*, (3), 62, 240, 1897.

37. A. Cotton, "Le Phénomène de Zeeman," p. 69.

38. G. E. Hale, "On the probable Existence of a Magnetic Field in Sun-Spots," *Contributions from the Mount Wilson Solar Observatory*, No. 30; *Astrophysical Journal*, 28, 315, 1908.

39. P. Zeeman and B. Winawer, "The Magnetic Separation of Absorption Lines in connection with Sun-spot Spectra," *Verslagen Koninklijke Akademie Amsterdam*, 12, 584, 1910; 13, 35, 162, 1910; *Astrophysical Journal*, 32, 329, 1910.

40. A. S. King, "The Correspondence between Zeeman Effect and Pressure Displacement for the Spectra of Iron, Chromium, and Titanium," *Contributions from the Mount Wilson Solar Observatory*, No. 46; *Astrophysical Journal*, 31, 433, 1910.

41. W. J. Humphreys, (*a*), "An Attempt to Find the Cause of the Width and of the Pressure-Shift of Spectrum Lines," *Astrophysical Journal*, 23, 233, 1906.
    (*b*), "Arc Spectra under Heavy Pressure," *Astrophysical Journal*, 26, 18, 1907.
    (*c*), "Note on the Cause of the Pressure-Shift of Spectrum Lines," *Astrophysical Journal*, 26, 297, 1907.
    (*d*), "The Luminous Particle a strong Magnet, and the consequent Pressure-Shift of Spectral Lines," *Astrophysical Journal*, 27, 194, 1908.

42. W. J. Humphreys, "Bericht über die Verschiebung von Spektrallinien durch Druck," *Jahrbuch der Radioaktivitat und Elektronik*, 5, 324, 1908.

43. O. W. Richardson, "A Theory of the Displacement of Spectral Lines produced by Pressure," *Philosophical Magazine*, (6), 14, 557, 1907.

44. J. Larmor, "Note on Displacement of Spectral Lines," *Astrophysical Journal*, 26, 120, 1907.

45. A. Dufour, "Sur un Cas Exceptional du Phénomène de Zeeman," *Comptes Rendus*, 146, 118, 1908. "Modifications anomales, dans le Champ Magnétique, des Spectres de Bandes de divers Composés," *Comptes Rendus*, 146, 229, 1908.

46. R. Rossi, "Pressure Effect on Band Spectra of Fluorides," *Proceedings Royal Society*, 82, 518, 1909.

47. A. Dufour, "Normale und anormale Veränderungen gewisser Banden in den Emissionsspektren der Moleküle verschiedener Körper in gasförmigem Zustande unter dem Einfluss eines Magnetfeldes," *Physikalische Zeitschrift*, 10, 124, 1909.

48. W. Hartmann, "Das Zeeman Phänomen im sichtbaren Spectrum von Kupfer, Eisen, Gold, und Chrom," Dissertation, Halle, 1907.

49. H. B. van Bilderbeek-van Meurs, "Magnetische Splitsing van het Ultraviolette Ijzerspectrum," Dissertation, Amsterdam, 1909.

50. J. E. Purvis, "The Influence of a Strong Magnetic Field on the Spark Spectra of Titanium, Chromium, and Manganese," *Proceedings Cambridge Philosophical Society*, 14, (1), 41, 1906.

51. A. S. King, "The Zeeman Effect for Titanium," *Contributions from the Mount Wilson Solar Observatory*, No. 39; *Astrophysical Journal*, 30, 1, 1909.

52. A. S. King, "On the Separation in the Magnetic Field of Some Lines occurring as Doublets and Triplets in Sun-Spot Spectra," *Contributions from the Mount Wilson Solar Observatory*, No. 34; *Astrophysical Journal*, 29, 76, 1909.

53. G. E. Hale, "The Pasadena Laboratory of the Mount Wilson Solar Observatory," *Contributions from the Mount Wilson Solar Observatory*, No. 27; *Astrophysical Journal*, 28, 244, 1908.

54. G. E. Hale, "The Tower Telescope of the Mount Wilson Solar Observatory," *Contributions from the Mount Wilson Solar Observatory*, No. 23; *Astrophysical Journal*, 27, 204, 1908.

55. R. J. Wallace, "Studies in Sensitometry, II—Orthochromatism by Bathing," *Astrophysical Journal*, 26, 299, 1907.

56. H. Kayser and C. Runge, "Ueber die Spectren der Elemente," *Abhandlungen Akademie der Wissenchaften Berlin*, 1888.

57. F. Exner und E. Haschek, "Wellenlangen-Tabellen der Funkenspektren der Elemente," Leipzig and Vienna, 1902.

58. J. N. Lockyer, "Tables of Wave-Lengths of Enhanced Lines," Solar Physics Committee, 1906.

59. B. Hasselberg, "Researches on the Arc Spectra of the Metals," *Astrophysical Journal*, 4, 116, 212, 1896.

60. P. Fiebig, "Untersuchungen über den langwelligen Teil des Titanspektrums," *Zeitschrift für Wissenschaftliche Photographie*, 8, 73, 1910.

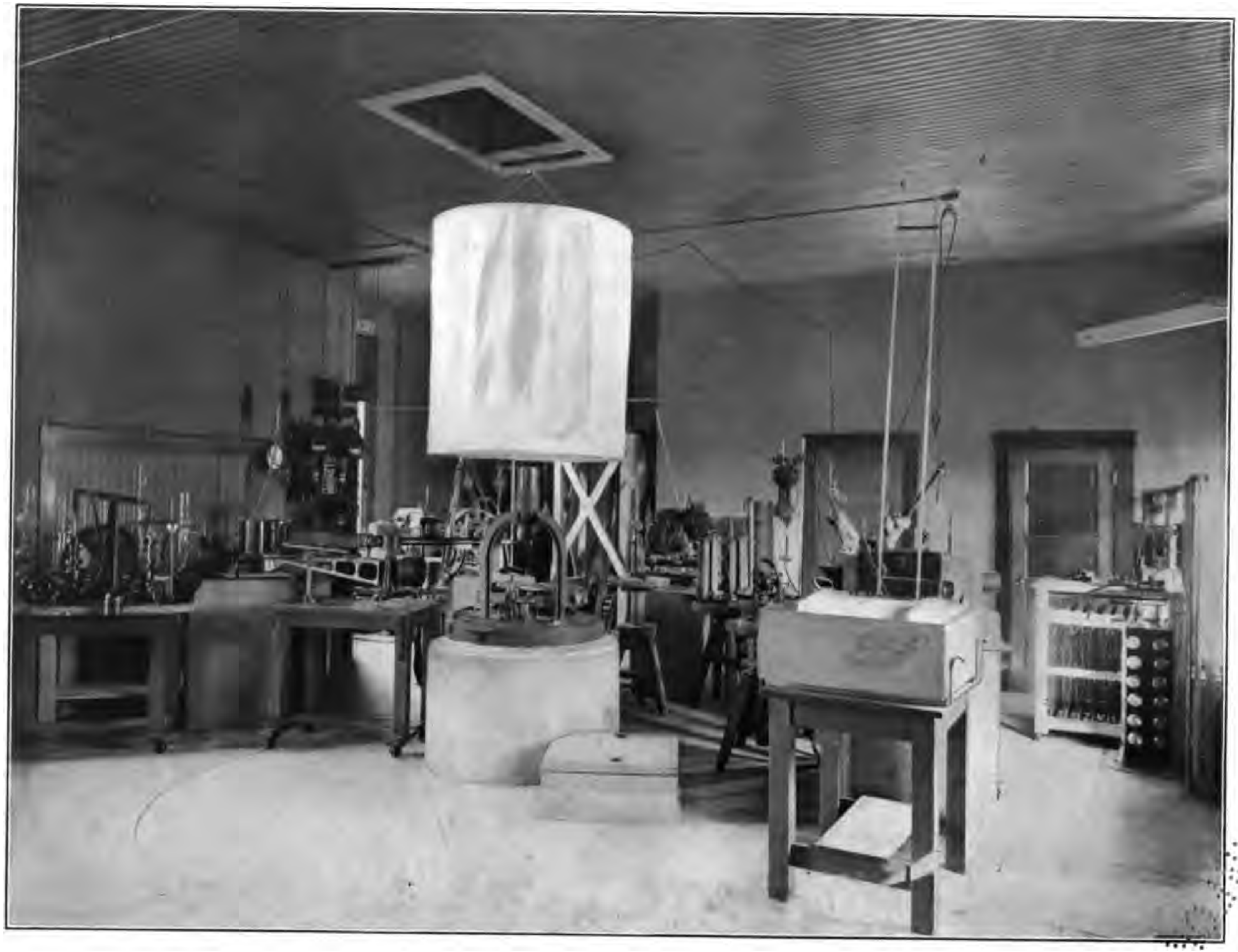
61. H. Buisson et C. Fabry, "Spectre du Fer," *Annales de la Faculté des Sciences de Marseille*, 17, 1908.

62. H. D. Babcock, "The Zeeman Effect for Chromium," *Contributions from the Mount Wilson Solar Observatory*, No. 52; *Astrophysical Journal*, 33, 217, 1911.
    "The Zeeman Effect for Vanadium," *Contributions from the Mount Wilson Solar Observatory*, No. 55; *Astrophysical Journal*, 34, 209, 1911.

63. A. S. King, "The Effect of Pressure upon Electric Furnace Spectra," *Contributions from the Mount Wilson Observatory*, No. 53; *Astrophysical Journal*, 34, 37, 1911.

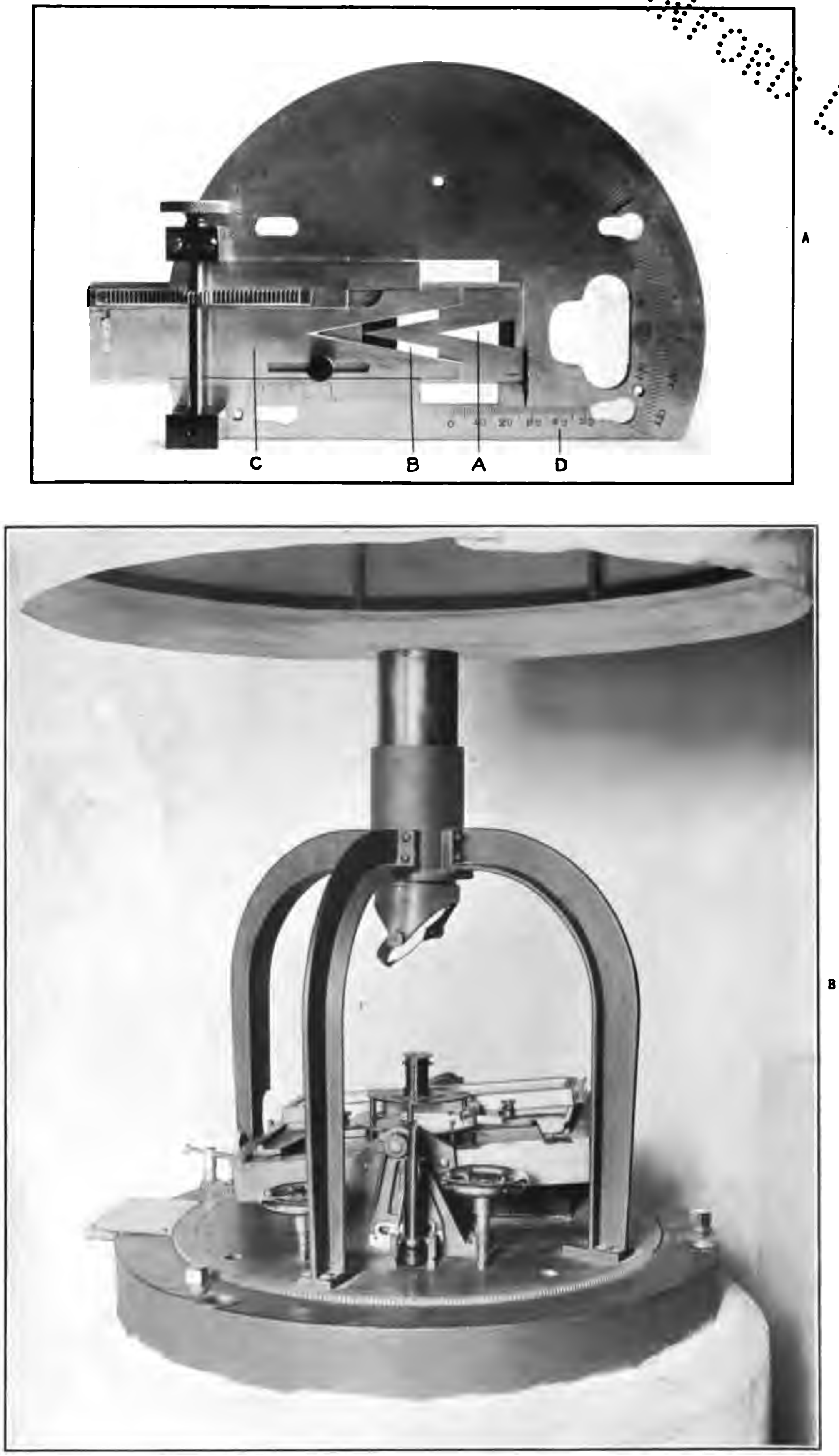
64. W. G. Duffield, "The Effect of Pressure upon Arc Spectra,—No. 1, Iron," *Philosophical Transactions, Royal Society, London*, A, 208, 111, 1908; (*a*), p. 160.

PLATE 1



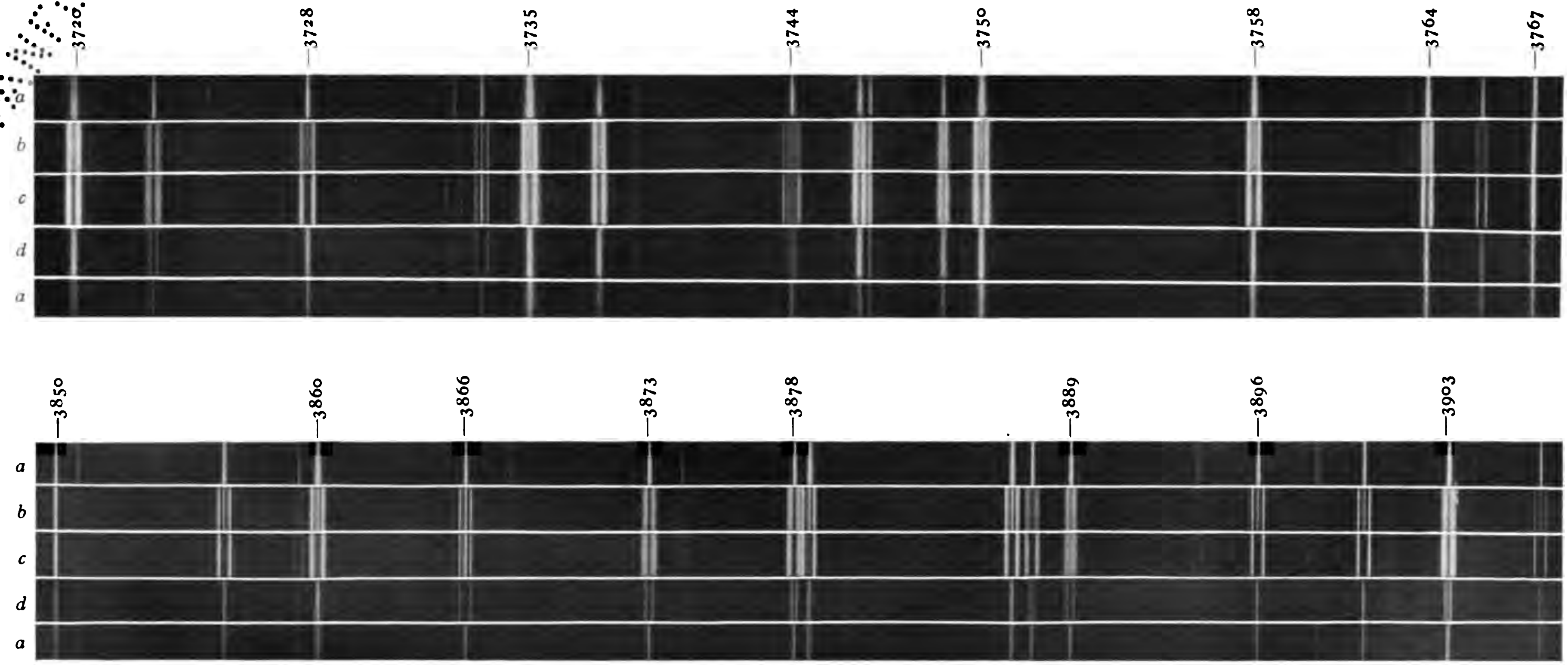
INTERIOR OF LABORATORY.

PLATE 2



A.—OCCULTING PLATE. B.—SPECTROGRAPH.

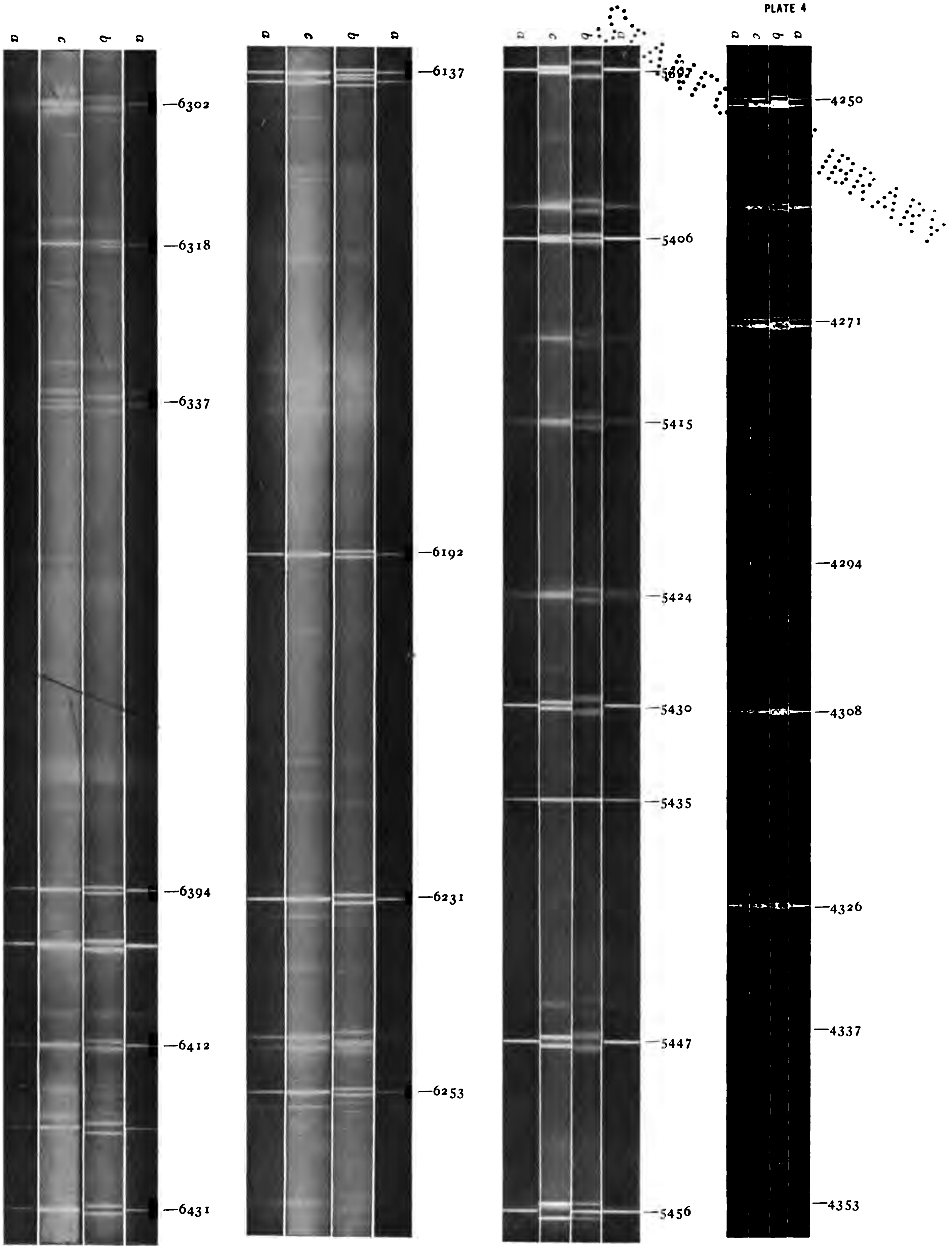
PLATE 3



EFFECT OF MAGNETIC FIELD ON THE SPARK SPECTRUM OF IRON.

a. Spark without field. *b*. Spectrum without Nicol, *n* and *p*-Components superposed. *c*. *n*-Components. *d*. *p*-Components.

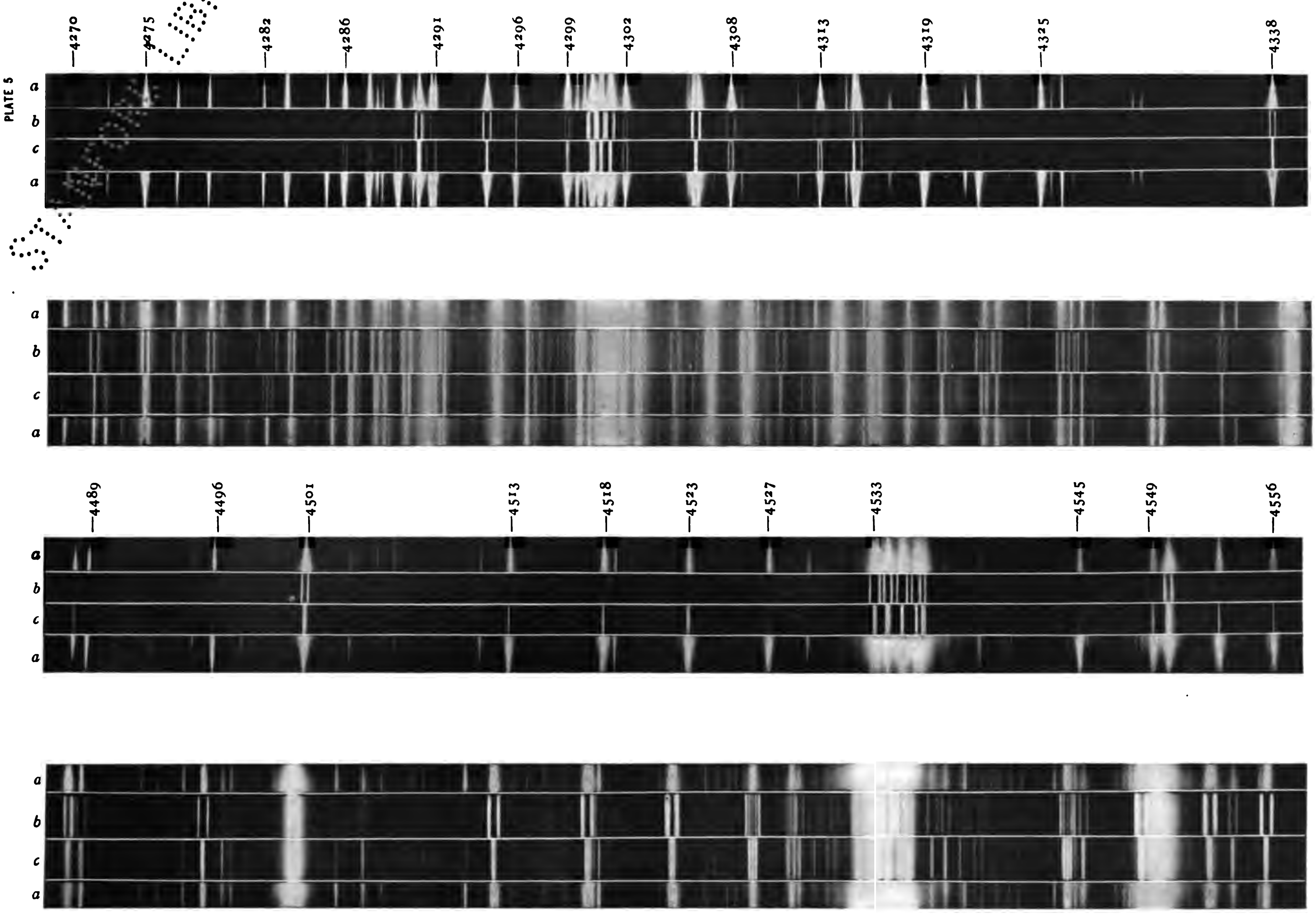
PLATE 4



EFFECT OF MAGNETIC FIELD UPON THE SPARK SPECTRUM OF IRON.

a. Spark without field. *b*. *n*-Components. *c*. *p*-Components.

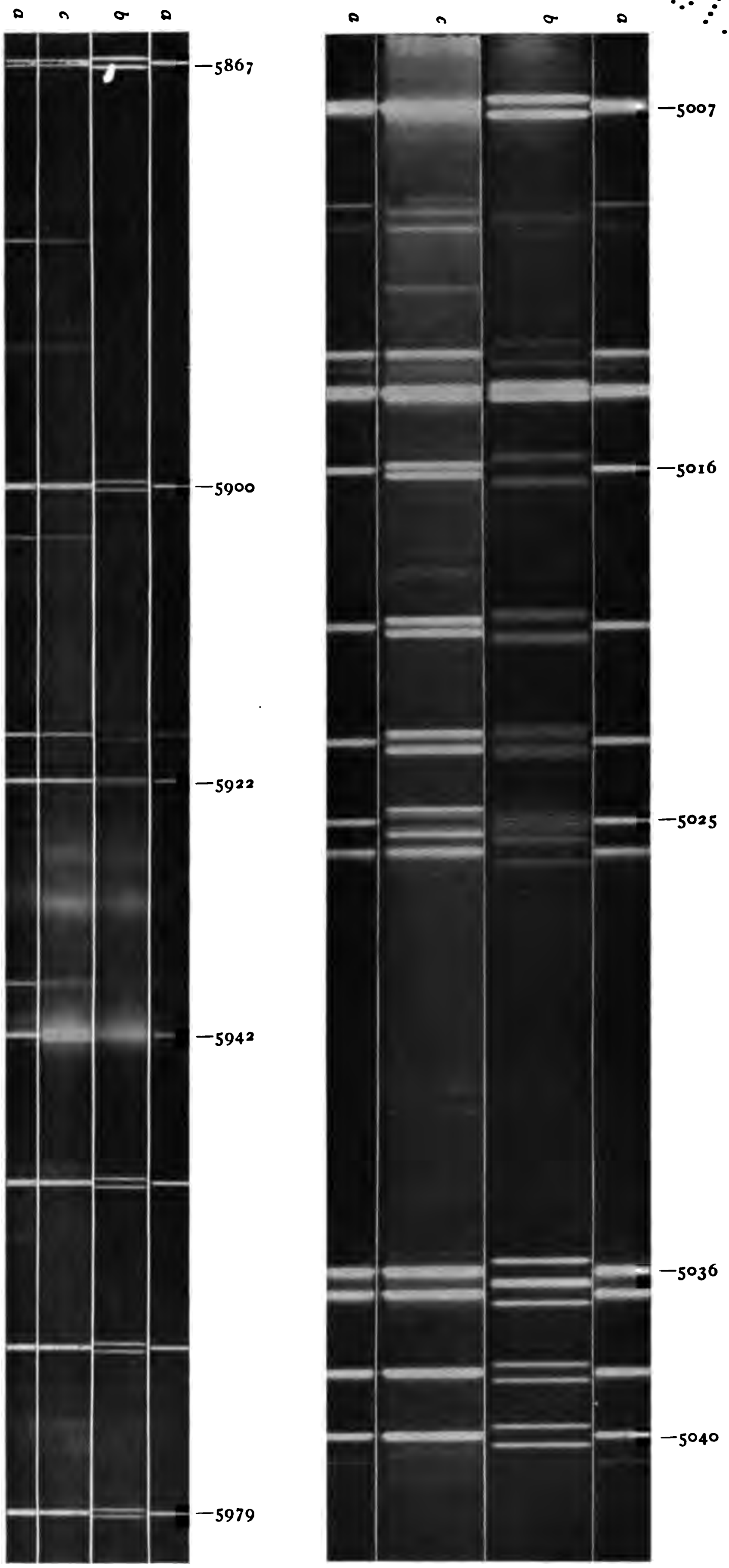
PLATE 5



EFFECT OF MAGNETIC FIELD UPON THE SPARK SPECTRUM OF TITANIUM.

Experimental conditions varied to bring out both strong and weak lines.
a. Spark without field. *b*. *n*-Components. *c*. *p*-Components.

PLATE 6



EFFECT OF MAGNETIC FIELD UPON THE SPARK SPECTRUM OF TITANIUM.

a. Spark without field. *b.* *n*-Components. *c.* *p*-Components.